science for a changing world

The National Water-Quality Assessment Program—Informing water-resource management and protection decisions

Background

The National Water-Quality Assessment (NAWQA) Program of the U.S. Geological Survey (USGS) is the primary source for long-term, nationwide information on the quality of streams, ground water, and aquatic ecosystems. During its first decade (1991-2001), NAWQA completed assessments in 51 major river basins and aquifers across the nation (known as “Study Units”; see map, last page). These assessments characterize the ambient water resource—the source for more than 60 percent of the Nation’s drinking water and water for irrigation and industry.

Completed NAWQA assessments provide baseline data and information on the occurrence of pesticides, nutrients, volatile organic compounds (VOCs), trace elements, and radon in water, and on the condition of stream habitat and fish, insect, and algal communities. Chemical and biological measurements are integrated with ancillary information on hydrology, land use, chemical use, and natural features, such as geology, soils, and climate, all of which help to explain where and why we see certain water conditions.

Each NAWQA assessment adheres to a nationally consistent study design and methods of sampling and analysis, so that water-quality conditions in a specific locality or watershed can be compared to those in other geographic regions. The consistent study design and methods also allow contaminants and aquatic ecology to be assessed on a *comprehensive national basis*. These assessments help us understand how and why water quality varies regionally and nationally.

During its second decade (2002-2012), NAWQA plans to reassess 42 of the 51 Study Units. These assessments will fill critical gaps in the characterization of water-quality conditions; determine trends at many of the monitoring sites; and build upon earlier assessments that link water-quality conditions and trends to natural and human factors.

Information from the NAWQA Program provides an unbiased scientific basis for decision makers, managers, and planners at all levels of government, as well as in nongovernmental organizations, industry, academia, and the public sector. NAWQA findings are used to address and prioritize the multitude of issues related to managing, protecting, and monitoring our water resources in many different hydrologic and land-use settings across the Nation.

“NAWQA is providing key national leadership in monitoring, reporting, and assessing the quality of surface water and groundwater resources across the Nation. Furthermore, NAWQA is playing a vital role in balancing its good science with responsiveness to policy and regulatory needs. Many states are using NAWQA data and findings in developing their resource management programs. This is a strong indication that NAWQA is providing valuable information to those managing water resources.”
(National Academy of Sciences, National Research Council, in [Opportunities to Improve the USGS National Water Quality Assessment Program], 2002).

How to Use this Document

This document summarizes some of the key findings in the first decade of studies by the NAWQA Program. It includes examples of how decision makers and planners at all levels—local, state, interstate, and national—use the information to meet their critical data needs; to fill in gaps in data for areas and resources they can not assess; and to make decisions for resource management and the protection of drinking water and aquatic ecosystems. Specific examples are provided on how NAWQA data are used to:

- Identify key sources of nonpoint pollution in agricultural and urban areas;
- Prioritize geographic areas and basins in which water resources and aquatic ecosystems are most vulnerable to contamination and where improved treatment or management can have the greatest benefits;
- Anticipate conditions in unmeasured areas;
- Understand trends;
- Support registrations and the development of regulations, standards, and guidelines that reflect actual contaminant occurrence, including contaminant mixtures, breakdown products, and seasonal patterns;
- Contribute to State assessments of beneficial uses and impaired waters (Total Maximum Daily Loads or TMDLs), strategies for source-water protection and management, pesticide and nutrient management plans, and fish-consumption advisories;
- Sustain the health of aquatic ecosystems through improved stream protection and restoration management;
- Improve strategies and protocols for monitoring, sampling, and analysis.

In this document, findings and examples are categorized by these key water issues to facilitate easy access for the reader who is looking for information on specific issues. Introductory information also is provided on the Nation's water-quality challenges and why and how the NAWQA Program was implemented and designed in 1991 to meet these challenges.

More detailed information on the NAWQA Program, and NAWQA findings, reports, maps, and data can be accessed directly at http://water.usgs.gov/nawqa.

"The New England Coastal Basins NAWQA study has been very valuable to the U.S. Environmental Protection Agency's New England regional water programs. The study has provided contaminated sediment data which will be incorporated into our National and regional sediment inventories; has highlighted the importance of arsenic in drinking water wells in New England; and has established relationships between land use and environmental quality of rivers and streams, including flow, nutrient status, and biological communities. The data from, and the monitoring approaches of, the study will help the USEPA in its monitoring and regulatory roles." (Matthew Liebman, U.S. Environmental Protection Agency-New England, June 2004, USGS Circular 1226)

"The USGS is an indispensable partner in local watershed management. The information from USGS is believable, dependable, scientifically sound, and—of greatest importance—immediately useful to those of us involved in day-to-day management of our watersheds. No other science agency has the same degree of local acceptance and relevance as USGS." (Mr. Dennis Bowker, Sacramento River Watershed Program, March 2001).

"In Nebraska, the issues of water quantity and quality are paramount policy concerns. The NAWQA process provides the scientific foundation on which sound public policy can be developed and pursued." (E. Benjamin Nelson, State of Nebraska, 2001, USGS Circular 1163).

Specific Topics Covered in this Document

NAWQA responds to national water-quality challenges

Our water resources are the basis for life and our economic vitality. These resources support a complex web of human activities and fishery and wildlife needs that depend upon clean water. Population growth and increasing demands for water, however, coupled with contamination from point and nonpoint sources, threaten the quality and quantity of our water resources.

Increasing demands for multiple beneficial uses, such as for drinking, agriculture, aquatic ecosystems, and recreation is challenging at all levels—local, State, interstate, and national—and requires us to better prioritize our water needs for high quality water, in conjunction with economic considerations. Water-quality challenges make these choices even more difficult, including:

- Most water-quality problems are caused by diffuse “nonpoint” sources of pollution from agricultural land, urban development, forest harvesting, and the atmosphere. These sources are more difficult to effectively monitor, evaluate, and control than point sources, such as discharges of sewage and industrial waste. Pollution from nonpoint sources varies in amount from hour-to-hour and season-to-season, making it difficult to monitor and quantify the sources over time.

- Water-quality issues have become more complex. Forty years ago, concerns about water quality focused largely on the sanitary quality of rivers and streams. Specifically, we were interested in bacteria counts, nutrients, whether there was enough oxygen in the water for fish, and a few measures like temperature and salinity. While these factors are still important, over the last 25 years new and more complex issues have emerged. Hundreds of synthetic organic compounds, like pesticides and volatile organic compounds (VOCs) in solvents and gasoline, have been introduced into the environment. Over the last five years, improved laboratory techniques have led to the "discovery" of microbial and viral contaminants, pharmaceuticals, and hormones that could not be measured before. Because these "emerging contaminants" have not been monitored previously, it is difficult to assess their effects on water quality and aquatic ecosystems.

- Evaluation and monitoring of pollution sources and the general state of U.S. water resources have been limited because available information is fragmented. Data must be pieced together from a variety of sources and studies, many of which are not designed to characterize nationwide water quality or changes over time. For example, state water-quality data have been inconsistent in types of information, analytical methods, and temporal and spatial scales. Therefore, as stated by the U.S. General Accounting Office in March 2000 in their report to the Congressional Subcommittee on Water Resources and Environment, the precise extent of water-quality problems, the nature and location of the severe problems, and the location of high-quality waters that need to be protected are still uncertain.

Responding to the Challenges—Recognizing these challenges, the Congress in 1991 established the National Water-Quality Assessment (NAWQA) Program of the U.S. Geological Survey (USGS). The goal was to develop long-term consistent and comparable information on nationwide water-quality conditions to support sound management and policy decisions. This information, collected in 51 major river basins and aquifers across the Nation, ensures an unbiased scientific basis for decision makers, managers, and planners at all levels of government to cost-effectively address a multitude of water-resource issues related to agriculture, urban development, drinking water, source-water protection, best management practices, Total Maximum Discharge Loads (TMDLs), hypoxia and excessive growth of algae and plants, pesticide registration, and monitoring and sampling strategies.

"USEPA values USGS as the principal source of high quality, accessible, and useful data on the nature, location, and characteristics of our Nation's water." (Tracy Mehan, former Assistant Administrator, USEPA Office of Water, during presentation of partnership award to the USGS, June 2003)

"The NAWQA Program does an excellent job at reporting its high quality, credible, and unbiased information in an understandable way that creates the needed links between science and water-resource policy. Our organization, which is a leader of a nation-wide river movement made up of thousands of river and watershed groups, depends on the water-quality and ecosystem data generated from this Program to help support the protection of our Nation's rivers." (Betsy Otto, Watersheds Program, American Rivers, November 2004)

"The NAWQA study results from the upper Illinois River assessment are extremely valuable to assist with efforts of water resource planning and management, given the potential predicted population growth, limitations on the use of Lake Michigan and the status of the sustained recharge of the deep aquifer system in northeastern Illinois." (Richard Cobb, Illinois Environmental Protection Agency, 2001)

"The USGS National Water-Quality Assessment work is the only systematic, basin-wide water quality work in the Yakima River Basin, [Washington] and a really important contribution to the understanding of what is going on and what we can do about it…from sediment to flows to biological uptake…USGS work has always been professional and unbiased. There have been few other entities that have provided such high caliber research and data collection. USGS work is used and respected by all parties in a basin where water-related controversies drive politics. In order to deal with issues such as 'saving the salmon' and developing TMDL's we need to have 'independent third parties' such as USGS working in the basin." (Brent Renfrow, Washington Department of Fish and Wildlife, November 2002)

"The USGS provides us [U.S. Fish and Wildlife Service] with top quality data that both the development community and the environmental community can trust. The USGS in Austin excels in quality control, quality assurance, and accurate reporting of water-quality data. This type of information forms the primary basis for many scientific decisions. Without your support our only choice would be to assume the "worse case" scenario, which could have more impacts than necessary on the development [of] communities within Central Texas. We need more water-quality information to understand the true interactions of chemical pollutants with our environment." (Matt Lechner, U.S. Fish and Wildlife Service, Austin, Texas, March 2001).

The NAWQA Design and Coordination

The NAWQA Program is shaped by and coordinated with ongoing efforts of other federal, state, tribal, and local agencies, and is designed to answer:

- What is the condition of our Nation's freshwater streams and ground water?
- How are conditions changing over time?
- How do natural features and human activities affect the quality of streams and ground water?

NAWQA assessments combine information on water chemistry, hydrology, land use, stream habitat, and aquatic life. Each assessment is an inter-disciplinary and long-term evaluation of the *total* resource, rather than an assessment limited to a specific geographic area or problem at a single point in time. Therefore, NAWQA findings describe the general health of water resources, as well on current and emerging water issues and priorities. For example, NAWQA assessments in the Sacramento River Basin showed that the Sacramento River and its major tributaries, such as the Feather and American Rivers, is generally suitable for drinking and irrigation water, recreation, and the protection of fish and other aquatic life. However, the findings also revealed that the insecticide diazinon is prevalent in some urban streams and that mercury is present at seasonally high concentrations in streams throughout the Sacramento River watershed. These findings help to set priorities for managers in the Basin.

It was recognized from the onset of the NAWQA Program that a national assessment by a single program could not possibly address or anticipate all current and future water-resource issues. Collaboration and coordination with numerous government, research, and interest-group partners, therefore, help to guide scientific efforts and ensure that NAWQA information will meet the needs of local, state, regional, and national stakeholders.

Since 1991, the NAWQA Program has included a national liaison committee (formerly referred to as the NAWQA Advisory Council), comprised of representatives from national, state, and regional organizations; professional and technical societies; public interest groups; private industry, and the academic community. This group helps ensure that NAWQA assessments address key national water issues. Also, the National Academy of Sciences, National Research Council conducts periodic reviews of the NAWQA Program and makes recommendations to ensure the best use of current scientific methods and approaches in NAWQA assessments.

Each individual NAWQA study worked with a liaison committee consisting of representatives with water-resources responsibilities or interests from federal, state, and local agencies, universities, public interest groups, and the private sector. Liaison committees were designed to (1) exchange information about water-quality issues of regional and local interest, (2) identify sources of data and information, (3) assist in the design and scope of project products, and (4) review planning documents and reports.

These local liaison committees have been very influential. For example, in response to concerns expressed by the liaison committee in Sacramento, California about mercury, NAWQA scientists worked with researchers in the USGS National Research and Toxics Hydrology Programs to develop procedures for collecting methylmercury in water (which was not a constituent typically measured by NAWQA at that time). Results from the preliminary sampling and analysis led to USGS collaborating further with California agencies, and extended USGS monitoring and research within the Sacramento River watershed, downstream in the delta of the Sacramento and San Joaquin Rivers, and the San Francisco Bay estuary.

"The NAWQA Program provides a critical national focus that helps to quantify the condition of our water resources in a large number of places. Its approach to providing nationally consistent information allows us to make statements that simply could not be made otherwise. Using NAWQA data, we can describe nutrient and contaminant occurrence nationally and among different land uses, and track how those conditions change over time. The Heinz Center depends heavily on NAWQA data to support our periodic report: "The State of the Nation's Ecosystems." We appreciate NAWQA's strong commitment to making its information and data readily accessible to meet our organization's needs and to address the Nation's water-resource information needs." (Robin O'Malley, The H. John Heinz III Center for Science, Economics and the Environment, November 2004)

"The area studied by the NAWQA program is the most heavily populated and developed area in Alaska. We regard NAWQA as a high quality, scientifically credible assessment effort that has furnished a significant amount of new information on watersheds in this area for which no, or very limited, information previously existed. Of particular value was the program's comprehensive approach which included surface water, land use, conventional pollutants, toxic pollutants, habitat, physical conditions, and biological components. The information obtained through this program complements our state monitoring efforts to understanding of water quality conditions within the Cook Inlet Basin. The reports produced have been well-written, informative, and contained excellent data evaluations, graphics, and maps. They are frequently consulted for information, and will continue to be consulted as important references for managing the area's water resources." (Ron Klein, Alaska Department of Environmental Conservation, Division of Air and Water Quality, June 2004, USGS Circular 1240)

"The NAWQA program has shown itself to be capable of generating high quality data of direct benefit to State agencies. NAWQA has provided the model for how different programs should work together and benefit from each other's research." (Robert Bode, New York State Department of Environmental Conservation, 2001, USGS Circular 1165).

"Southwestern Pennsylvania provides a good example of how a national-level program can generate water quality monitoring data at regional and local scales in a timely, responsive, and reliable manner that can be used in support of decision making. The NAWQA program, in particular, for several years sought to gain understanding of water quality conditions, trends, and stressors in the Allegheny and Monongahela basins but unfortunately, that focused effort has been terminated for budgetary reasons. Nonetheless, data collected on water quality are maintained by the USGS, are available to the public, and provide a long-term term, rich source to track changes and trends in water quality in the Allegheny Monongahela and Ohio Rivers." (National Academy of Sciences Report, "Regional Cooperation for Water Quality Improvement in Southwestern Pennsylvania", 2004)

"The Central Nebraska NAWQA Study is an invaluable benchmark of water quality data. The facilitative approach between federal, state and local levels of government in data development lends undeniable credibility to the process, the data, and to programmatic applications." (Dayle E. Williamson, Nebraska Natural Resources Commission, 2001, USGS Circular 1163).

"The NAWQA Program should be commended for putting together an excellent database on water quality conditions in the [San Joaquin] Basin. Their study, which was summarized in USGS Circular 1159, is an example of what can be done when the USGS staff cooperates with the state and local agencies within the basin. Working with other agencies, your staff identified the water-quality concerns that were a priority for these agencies and then developed the database to document, in a purely scientific way, the extent of that problem. Granted, this is not an end in itself but it set the stage for focusing resources within the watershed on the most serious issues." (Dennis W. Westcot, Environmental Program, California Regional Water Quality Control Board, August 6, 1998).

"In New Mexico, we are particularly pleased with the NAWQA effort on the Rio Grande. We were in great need of reliable, scientific data from which to assess the health of the river system. Now we are able to use these data to improve our management of this vital water resource." (Bobby J. Creel, New Mexico Water Resources Research Institute, 2001, USGS Circular 1162).

"Actual water-quality data shows us where our efforts to protect the environment are successful and what still needs to be done to prevent pollution. We depend on this valuable partnership with the U.S. Geological Survey, in cooperation with our communities, as we continue our work to protect and restore Pennsylvania's watersheds." (James M. Seif, Pennsylvania Department of Environmental Protection, 2001, USGS Circular 1168).

"The U.S. Geological Survey's Willamette Basin NAWQA Program is a high quality, scientifically credible water quality assessment. The program took a comprehensive approach, which included ground water, surface water, land use, conventional pollutants, toxic pollutants, habitat, physical conditions, and biological components. The information obtained through this program complements our state monitoring efforts to provide a much more accurate and complete understanding of water quality conditions within the Willamette watershed. Such an understanding is essential to the wise and effective management of these treasured water resources and their protection for present and future generations." (Greg Pettit, Water Quality Monitoring, Oregon Department of Environmental Quality, 2001, USGS Circular 1161).

"As the state geologist of 'The Natural State,' I have a special interest in its water resources and a commitment to further our geohydrologic knowledge. Data collected through the NAWQA Program are helpful in evaluating, protecting, and managing our bountiful water resources." **(**William V. Bush, Arkansas Geological Commission, 2001, USGS Circular 1158).

"The scientific and technical information contained in this [NAWQA] report provides valuable assistance in California's efforts to better understand and implement programs to address water resource issues—not only in the San Joaquin-Tulare Basins, but throughout the state." (Walt Pettit, California State Water Resources Control Board, 2001, USGS Circular 1159).

"As a representative of a Canadian natural resources agency, I feel that the extensive knowledge generated by the NAWQA study of the Red River on key environmental issues and underlying processes has given Canadian stakeholders a better understanding of transboundary issues and will contribute significantly to the management of the entire watershed." (Dr. John Wood, Environment Canada, Regina, Saskatchewan, 2001,USGS Circular 1169).

"In partnership with the NAWQA Program, we collected a significant amount of ground-water-quality data that neither agency could have obtained individually. The data provide an important snapshot of the overall health of ground water –the region's primary source of drinking water. The information generated through this partnership will help our region formulate more effective ground-water management strategies in the future." (Michael P. Ekberg, Miami Conservancy District, June 2004, USGS Circular 1229)

Identifying key sources of nonpoint pollution in agricultural and urban areas

"The Acadian-Pontchartrain Drainages NAWQA program has contributed valuable information to the U.S. EPA's Office of Pesticide Programs' (OPP) understanding of the occurrence of pesticides in ground and surface water in one of the Nation's major rice and sugarcane production areas. As a reliable source of comprehensive information, results from the USGS study unit have been used in pesticide exposure and risk assessments. The OPP has found the data useful in understanding the relationship between land use (e.g., agriculture) and the frequency and levels of pesticide detections in water." (Sid Abel, Environmental Fate and Effects Division, Office of Pesticide Programs, U.S. Environmental Protection Agency)

NAWQA studies indicate that contaminants are widespread, albeit often at low concentrations, in river basins and aquifer systems across a wide range of landscapes and land uses. Nationally, at least one pesticide was found in about 95 percent of water samples and in 90 percent of fish samples from streams, and in about 55 percent of shallow wells sampled in agricultural and urban areas.

The type and concentrations of contaminants that are found in urban and agricultural water resources are closely related to the chemicals that are used (such as fertilizers and pesticides) or that are released with waste products (such as sewage or manure). For example, phosphorus and many insecticides, such as diazinon, carbaryl, chlorpyrifos, and malathion, were detected more frequently and usually at higher concentrations in urban streams than in agricultural streams. Nationally, at least one pesticide guideline established to protect aquatic life was exceeded in nearly all (about 93 percent) urban streams sampled.

Nitrogen and many herbicides-most commonly atrazine and its breakdown product deethylatrazine (DEA), metolachlor, alachlor, and cyanazine—generally were detected more frequently and usually at higher concentrations in streams and shallow ground water in agricultural areas than in urban areas. Occurrence is linked to use; these herbicides rank in the top five used for agriculture. Concentrations of nitrate exceeded the USEPA drinking-water standard of 10 milligrams per liter in samples collected from about 20 percent of shallow wells in agricultural areas (versus about 3 percent in urban areas).

VOCs were detected frequently in shallow ground water beneath urban areas (in about 90 percent of monitoring wells sampled) and less frequently in shallow ground water beneath agricultural areas (in 20 percent of monitoring wells). Some of the most common VOCs in urban areas were the solvents trichloroethene (TCE), tetrachloroethene (PCE), 1,1,1-trichloroethane (TCA), and trichlormethane (also known as chloroform), which is a disinfection by-product of water treatment; and the gasoline-related compounds benzene, toluene, xylene, and methyl *tert*-butyl ether (MTBE).

Upper Gunnison River Watershed, Colorado—A consortium of water, sanitation, and river districts, towns, counties, and the National Park Service in the Upper Gunnison River watershed, Colorado, use NAWQA findings to assess the occurrence and sources of contaminants in the developing areas and to determine the health of the watershed, given an urbanization rate of about 200 percent between 1970 and 1990. NAWQA findings on surface- and ground-water quality inform decisions related to wastewater facilities versus traditional septic systems, and help to implement annual septic-system monitoring to prevent further water-quality degradation.

***State of New Jersey*—**The New Jersey Office of State Planning collaborates with USGS to develop a computer model that forecasts the effect of land-use development on freshwater quality. NAWQA findings and data are the foundation on which the model is based. The model helps to educate local planning boards about nonpoint source pollution and allows municipalities and local planning officials to visualize the impacts of urban development on freshwater resources in their communities.

***Austin, Texas*—**In 1997, the NAWQA Program collected sediment cores from Town Lake in Austin, Texas, which revealed rapidly increasing concentrations of PAHs (polycyclic aromatic hydrocarbons) and decreasing but continued levels of DDT and chlordane. These compounds most likely originate from the City of Austin because the lake receives significant input from the urban streams. As a result of these findings, the City of Austin collaborated with USGS to assess sediment chemistry in the urban streams and to track sources of the PAHs, along with metals and historically used organochlorine pesticides, such as DDT and chlordane.

"The NAWQA approach of relating surface-water quality to land use will help us manage water resources in portions of the Missouri Ozarks now undergoing significant land-use change." (John Ford, Missouri Department of Natural Resources, 2001, USGS Circular 1158).

Managing chemical use

Localities and States recognize that chemical-use tracking is a critical first step to understanding and managing effects on water resources. Reducing chemical use and improving disposal practices can help reduce the contaminant concentrations in both urban and agricultural settings. More information about chemical use—data that are virtually unavailable in urban areas—is critical to linking contaminants to their sources, thus helping individuals, businesses, and industry as well as local, State, and Federal governments to improve water quality.

***King County, Washington*—**USGS has worked with King County, Washington to better understand relations between pesticide use and occurrence in urban streams. In King County, 23 of 98 pesticides were found in streams in 10 urban and suburban watersheds. Homeowner use was indicated as the source of some insecticides, such as diazinon, and some herbicides, such as 2,4-D, which are commonly sold in home and garden stores. The county uses a USGS fact sheet ("Pesticides in Selected Small Streams in the Puget Sound Basin, 1987-1995," USGS FS-067-97) as an educational tool in an effort to encourage homeowners to use fewer pesticides on lawns and gardens. Almost half of the pesticides found in the streams had no retail sales within Seattle or the surrounding area, indicating that commercial applications, such as along road rights-of-way, are potential sources of these pesticides in streams. This information helps local officials to manage chemical use.

***State of Oregon*—**A NAWQA study detected numerous pesticides in agricultural and urban streams in the Willamette Basin, Oregon. Many of the compounds occurred at elevated concentrations, often exceeding guidelines to protect aquatic life. Lack of information on pesticide use, however, limited a direct assessment of the source of the pesticides and how they were transported to the water. Concerned citizens and a broad coalition of stakeholders used these findings to support a law that requires reporting of pesticide use in Oregon. The bill, which passed both the Oregon House and Senate by wide margins and had the support of both environmentalists and pesticide users, made Oregon the third state (after California and New York) to require pesticide-use tracking. A unique feature of Oregon's law is the provision for reporting pesticide use in urban areas, including home and garden use.

State of New Jersey**—**NAWQA findings showed that nitrate contamination of shallow ground water underlying areas of high nitrogen fertilizer use in southern New Jersey is expected to affect 100-foot-deep public drinking wells over the next 50 years. On the basis of this and other water-quality information, the New Jersey Department of Environmental Protection works with the agricultural community to minimize the use of fertilizers and pesticides and implement best management practices.

Improving land-management practices

Localities and States recognize that land-management practices can improve nonpoint pollution in agricultural and urban areas.

Yakima River Basin, Washington— NAWQA findings show water-quality improvements from best-management practices in the Yakima River Basin, Washington. Irrigation Districts in the Yakima River Basin have implemented best management practices, such as shifting from furrow to sprinkler irrigation, to reduce water-quality degradation. NAWQA findings over the last decade show that these practices have reduced the loss of soil from irrigated cropland and have minimized the transport of contaminants that attach to soil particles, such as the insecticide DDT and phosphorus.

Rockingham County, Virginia— NAWQA findings on nutrients, pesticides, and bacteria levels in the Muddy Creek basin in Rockingham County, Virginia showed significant degradation because of dairy and poultry farming and intensive row cropping. The information was used by Rockingham County and other watershed organizations to implement fencing alternatives and other land-management practices to protect the basin’s water resources. The county accelerated these changes when the information was placed in a national context, which ranked water quality in Muddy Creek among the most degraded of all agricultural streams (about 120) sampled by USGS.

Northwestern Ohio and northeastern Indiana— Conservation tillage, which is a reduced-cultivation method, has been implemented in about 50 percent of crop fields in the Maumee River Basin and in northwestern Ohio. NAWQA findings from 1993-98 in the Maumee and Auglaize River Basins showed significant decreases in the amounts of suspended sediment carried by the Maumee and Auglaize Rivers, which are large tributary sources to Lake Erie. These findings and trends will help the Ohio Lake Erie Commission and the U.S. Army Corps of Engineers to track progress towards their sediment-reduction goals of 15 and 67 percent from conditions in 1992.

Assessing and prioritizing geographic areas and basins in which water resources and aquatic ecosystems are most vulnerable

Chemical-use tracking, source identification in agricultural and urban areas, and land-management practices are not enough to effectively manage nonpoint pollution. Decision makers and managers also need to understand the movement of water and the transport of contaminants through a watershed, which, in large part, is controlled by natural features and hydrologic connections between ground water and surface water. This would be relatively trivial if all watersheds responded similarly to sources of contamination, chemical use and land-management practices. However, NAWQA findings clearly show that differences in these natural features and hydrologic factors can result in very different degrees of vulnerability to contamination and different rates at which improved management can lead to improved water quality. Understanding these concepts determines the timing and success of appropriate management decisions and actions and helps to prioritize where improved treatment or management can have the greatest benefits. Because vulnerability to contamination can differ from place to place, a national strategy for managing nonpoint source pollution should consider local and regional differences in natural features.

Effects of natural features

Natural features, such as geology, climate, hydrology, and soils, control the transport of chemicals as they move from land to streams and then downstream to reservoirs and coastal waters, and they move from land to shallow ground water and underlying aquifers. For example, ground water is vulnerable to nitrate contamination in well-drained areas with permeable soils that are underlain by sand and gravel such as in the Platte River Valley in Colorado and Nebraska, or in karst (fractured carbonate rocks) in parts of Florida and the Susquehanna and Potomac River Basins in Pennsylvania, Maryland, and Virginia. These settings facilitate relatively rapid downward movement of water. In contrast, streams generally are most vulnerable to contamination in basins with poorly drained clay soils, steep slopes, or where sparse vegetation does not slow runoff.

***Ogalla Aquifer, High Plains*—**Data demonstrating the occurrence of pesticides in ground water in the High Plains/Ogallala aquifer of northwestern Oklahoma has indicated that much of the water in the aquifer might have been recently recharged. Widespread detection of pesticides in the aquifer has refuted the conventional wisdom that ground water takes hundreds or thousands of years to recharge the Ogalla Aquifer and has indicated a much greater vulnerability in parts of the aquifer to contamination. Results from the NAWQA program have served as an impetus to increased monitoring of the effects of land-use practices, and in particular swine confined animal feeding operations (CAFOs) in the High Plains.

***Island of Oahu, Hawaii*—**The deep volcanic-rock aquifer in central Oahu and Honolulu supplies more than 90 percent of the island's public-water supply and is a designated Sole Source Drinking-water Aquifer. The aquifer is highly permeable and unconfined except near the coast, and is vulnerable to contamination despite the deep water table (100 to 1,000 feet deep). Solvents were detected in the drinking-water aquifer throughout central Oahu, with highest concentrations beneath urban areas and military installations. Fumigants, herbicides, and elevated nutrients were prevalent in ground water beneath central Oahu agricultural lands. To the southeast in urban Honolulu, few contaminants were detected in drinking-water wells due to a century of urban planning and watershed protection that has directed intensive chemical use and storage away from upland recharge areas of Honolulu.

North Atlantic Coastal Plain Indicators Model—USEPA researchers have collaborated with NAWQA scientists in the North Atlantic Coastal Plain to develop logistic-regression models and maps that predict the occurrence of selected nutrients and pesticides in first-order streams during base flow conditions (which are comprised, in large part, from ground-water discharge). The models incorporate key landscape indicators, such as geology and soils that help to explain the transport of nutrients and pesticides from ground water to surface water and their effects on aquatic biota. The information could be used to assess vulnerable areas of the Coastal Plain, and is useful for federal managers within the EPA Office of Pesticides and Office of Water who are charged in nutrient and pesticide management and protection, as well as in the EPA Chesapeake Bay Program who are charged with improved goal setting and management of water-quality conditions in the Chesapeake Bay estuary. In addition, the modeled findings are useful at the State level, such as in the development of State TMDLs, pesticide management plans, nutrient management criteria, and source-water protection.

"The insights and information that came from the NAWQA Mid-Atlantic Coastal Plain Synthesis Project served as the base for the design of the EPA 'Landscape Indicators for Pesticides' study. This study is the first time this particular stratified random design has been applied in a large monitoring study. The study has further benefited from the blending of expertise and talents from EPA and USGS scientists (with specialties in landscape ecology and hydrology, etc). This combination of expertise has enabled us to address the pesticide and nutrient issues in a comprehensive manner." (Ann Pitchford, U.S. Environmental Protection Agency-Las Vegas, March 2001).

Sussex County, Delaware—NAWQA studies in Sussex County, Delaware showed that ground water, which supplies more than half of the water to streams in this region, travels very slowly—about a foot a day—through this aquifer system. County officials now understand that improvements in ground water and stream quality can lag behind changes in fertilizer use and implementation of land-management practices by many years and even decades.

Importance of surface-water and ground-water relations

Groundwater can be a major contributor to streams and rivers, and contaminated aquifers that discharge to streams can thereby serve as nonpoint sources of contaminants to surface water. Quantifying the contribution is, therefore, a critical step in developing water-quality standards and criteria, issuing permits, and meeting Clean Water Act goals for swimmable, fishable, and drinkable waters. Typically, groundwater inputs are not included in estimates of contaminant loads in streams. Section 303(d) of the Clean Water Act requires States to identify waters that are impaired by pollution and to establish a Total Maximum Daily Load (TMDL) of selected pollutants to ensure that water-quality standards can be attained. The TMDL is intended to quantify all pollution sources, including point discharges from municipalities and industry and nonpoint sources. The TMDL process should include groundwater in order for all pollution sources to be considered and for the process to be effective in protecting and restoring streams.

Similarly, surface water can be a major contributor to groundwater, and can serve as a major nonpoint source of contamination to aquifers, particularly where high-capacity public-supply wells are located near streams and rivers. Groundwater is generally thought to be safe for consumption without water treatment. However, groundwater from wells near streams can host the same contaminants as the surface water recharging the well. Water managers should consider such connections in the design of source-water and well-head protection strategies.

Contaminants generally are more prevalent and detected at higher concentrations in streams than in ground water. This largely is determined by chemical properties of contaminants and flow conditions-ground water typically is not vulnerable to contamination by compounds that attach to soils or that are unstable in water, and relatively long residence times along groundwater flow paths allow many chemicals to degrade, disperse, or be diluted before reaching a well.

"The combined surface- and ground-water quality and ecological assessments of the Flint River Basin by the Lower Tennessee River Basin NAWQA Program have heightened our awareness of how vulnerable our water resources are due to karst features of the watershed. These technical, interdisciplinary assessments of watershed conditions have helped focus our watershed restoration efforts within the Flint River Basin." (Susan Weber, Flint River Conservation Association, June 2004, USGS Circular 1233)

As indicated in the examples below, interactions between streams and ground water are affected by natural features such as soils, geology, and hydrology, and by human activities such as ground-water pumping and regulated controls, including dams and ground-water recharge ponds.

San Antonio, Texas— NAWQA findings in San Antonio, Texas showed that major streams lose substantial amounts of water to the nearby highly permeable, faulted and fractured carbonate outcrop of the Edwards aquifer. The streams, in large part, originate in and flow through what is now mostly undeveloped rangeland; however, these streams also flow through northern San Antonio, which continues to be developed. Some contaminants that are typical of urban runoff are finding their way to the recharge zone and ultimately to the aquifers. For example, chloroform along with the herbicides atrazine, deethylatrazine, simazine and prometon were commonly detected in NAWQA samples from wells in the recharge zone. Findings on water quality in the Edwards aquifer and in the recharging streams point to a critical management issue for the region because the aquifer is the principal water supply for the greater San Antonio region.

Washington State - Historical mining in northern Idaho has resulted in elevated concentrations of some trace metals, particularly cadmium, lead, and zinc, in water and sediments in the Spokane River. These elevated trace-metal concentrations have raised the concern of residents and officials from the Washington Department of Ecology and Spokane County about their transport and potential contamination of the underlying Spokane Valley/Rathdrum Prairie aquifer, the primary source of drinking water for over 400,000 people in and around the city of Spokane. Hydrologic and chemical data collected as part of NAWQA indicate that the Spokane River recharges the aquifer between Coeur d'Alene Lake and Spokane. The data showed that although zinc concentrations in near-river wells were slightly elevated as a result of river recharge, all trace-metal concentrations were well below drinking- water standards.

"Understanding river and aquifer interaction often is critically linked to the consumptive needs of our citizenry, stream aquatic life, and riparian health, and ultimately our quality of life. Focused USGS scientific studies are assisting state and local government to protect water quality, manage water resources, and preserve natural systems, such as the Spokane River and Spokane Valley-Rathdrum Prairie Aquifer in Washington and Idaho." (John L. Roland, Washington State Department of Ecology, June 2004, USGS Circular 1235)

City of Lincoln, Nebraska—NAWQA findings showed that ground-water withdrawals from the alluvial aquifer induces infiltration from the Platte River to the underlying aquifer where public-supply wells supply about 117 million gallons per day to Nebraska's large cities, Omaha, Lincoln, Grand Island, and Kearney. Of similar concern in the Central Nebraska Basins is the heavy agricultural use of fertilizers and herbicides, such as atrazine, alachlor, cyanazine, and metolachlor. For example, elevated concentrations of atrazine were detected in public-supply wells in the Ashland well field, the primary source of public supply for the City of Lincoln, which has a population of about 200,000. NAWQA samples from the well field had atrazine concentrations as high as 20 micrograms per liter, far exceeding the USEPA drinking-water standard of 3 micrograms per liter. The USGS studies improved the City's understanding of the transport of pesticides from the Platte River through channel alluvium and into the ground water at the City of Lincoln well-field near the river. NAWQA findings are used by the City of Lincoln to update a well-field management plan.

"Studies and research that we have directly co-sponsored with USGS and the NAWQA preliminary work has assisted us in setting up an early warning system for our well-field management plan." (Jerry Obrist, Lincoln Public Works & Utilities Department, October 2004)

***Southern California*—**NAWQA findings showed that controlled and regulated water management can greatly affect transport of water between surface-water and groundwater systems, as demonstrated in southern California where flow of the Santa Ana River is used to recharge the ground-water system for public supply. Groundwater recharge facilities are located along rivers and streams draining the San Gabriel, San Bernardino, and San Jacinto Mountains, and along and adjacent to the Santa Ana River in the Coastal Basin. About 200 million gallons per day are recharged to the Coastal Plain aquifers to help balance the total amount of groundwater pumped from the aquifer used for public supply. The quality of water in aquifers in the Santa Ana Basin therefore reflects the quality of stream flow during the last 50 years, which is the average time that water remains in the groundwater system. NAWQA samples indicated elevated chloroform, a byproduct of water disinfection, widely distributed in the aquifer. MTBE also was commonly detected, although not as widespread as chloroform. The results indicate that yesterday's surface water is today's ground water and therefore remind us of the importance of protecting it as a single resource.

Anticipating (modeling) conditions in unmeasured areas

NAWQA assessments of water quality conditions and their relations to natural and human factors (as described in previous sections) provide a foundation for estimating the occurrence and distribution of selected chemicals at unmonitored sites under a range of possible circumstances, supported through the development and validation of statistical predictive models.

These models are essential tools for cost-effect management of our water resources because managing contaminants requires far more information than we can afford to directly measure for all the places, times, and contaminants that are important. In addition, many management decisions—including how much to spend on implementing a management strategy, monitoring priorities, and approving a compound registrations—inherently depend on predicting the potential effects on water quality for locations that have never been measured.

The NAWQA models integrate information on water quality, chemical use, land use, and environmental factors that help to explain water-quality conditions over broad regions. In general, the NAWQA Program, thereby, uses a regression approach with results in expressions of statistical correlations between water-quality concentrations or detections and those natural or human factors that influence the concentrations. Specifically, modeled estimates are made from associating measurements of concentrations or frequencies with known contaminant sources (such as estimated chemical use), as well as land-management practices (i.e. irrigation and tile drains) and characteristics of each hydrology and landscape (i.e. soils, geology, and climate), both of which affect and control the transport of the chemicals within the watersheds and ultimately to streams, rivers, and ground water.

A strong emphasis is placed on the development of predictive models and other tools in the second decade of NAWQA assessments. Such tools will be useful to water managers and scientists in assessing resource vulnerability and sustainability for future supply across broad regions and in developing cost-effective monitoring programs.

National-scale models

NAWQA has completed national extrapolations using regression models for atrazine concentrations in stream water, for concentrations of dieldrin in fish tissue, and for detection frequency of atrazine and concentrations of nitrate in shallow ground water beneath agricultural areas.

***NAWQA estimates atrazine concentrations in streams across the Nation*—**NAWQA used national data to develop a watershed regression model, which estimates the occurrence and exposure to atrazine for watersheds across the country. Modeled findings showed that key factors affecting concentrations are atrazine use, the size of the watershed, overland flow, rainfall, and soil erodibility. These five factors help to explain about 80 percent of the variance in annual mean concentrations of atrazine among the sites across the Nation. Results indicate that only a few streams that have greater than a 50 percent probability that the actual average concentration of atrazine exceeds 3 micrograms per liter, which is the USEPA drinking-water standard for atrazine. These streams are located in the Ohio and Mississippi Valleys and in southern Louisiana.

"For many years, EPA has worked closely with the USGS NAWQA Program to advance the scientific tools and data that are used to assess risks posed by pesticides in surface water and ground water. Recently, the two agencies have collaborated in developing an extrapolation model that will statistically relate pesticide concentrations to watershed characteristics. Using national data, this model, called WARP (Watershed Regression Program), estimates

occurrence and exposure to atrazine for watersheds across the country, with calculated reliability. The model increases EPA's capability to predict potential impacts of pesticide use on water quality, especially in areas where monitoring data are not available and has been used to identify areas where additional monitoring is most needed to evaluate the ecological condition of watersheds." (Elizabeth Behl, Environmental Risk Branch, U.S. Environmental Protection Agency, November 2004)

NAWQA helps to predict pesticide contamination in sources of drinking water for USEPA's pesticide regulatory process – NAWQA, in cooperation with USEPA and industry representatives, has developed statistical models and a national database containing locations of drinking-water intakes, watershed boundaries, and pesticide use. The models are used to help estimate pesticide concentrations at unmonitored sites in streams and rivers used as sources of drinking water. The estimates are used by the USEPA to implement the Food Quality Protection Act (FQPA), which requires estimation of human exposure to pesticides in drinking water.

NAWQA estimates risks of nitrate contamination to shallow ground water**—**A nitrate model, based on nationwide data, was developed to estimate the risk of nitrate contamination to shallow ground water across the Nation. The model highlights areas where nitrate more likely occurs, such as in the High Plains of northeastern Nebraska and northwestern Texas, and helps to explain why some areas are associated with higher probabilities of nitrate contamination. Specifically, the likelihood of nitrate contamination of shallow ground water is greatest in areas with high nitrogen input (associated with nitrogen fertilizer applications and high population densities) and well-drained soils that overlie unconsolidated sand and gravel aquifers. The national map is used by USEPA and others involved in developing resource management strategies for prioritized monitoring, protection, and restoration. (Map is accessible at http://water.usgs.gov/nawqa). By targeting regions with the highest risk of nitrate contamination, resources can be directed to areas most likely to benefit from pollution-prevention programs and long-term monitoring. Use of risk guidelines to locate areas for prevention of contamination also can result in cost-effective management. Once ground water is contaminated, it is expensive and, in many cases, virtually impossible to clean up.

NAWQA models the detection of atrazine in shallow ground water across the Nation**—** NAWQA findings showed that the detection of atrazine in shallow ground water beneath agricultural areas can be estimated, in large part, by knowing the amount of agricultural land, the amount of tiles or other subsurface drainage, water capacity of the soil, and vertical permeability of the soil. Atrazine use has an important influence on the occurrence of atrazine in shallow ground water, but not as important as for streams. Atrazine occurrence in shallow ground water is not necessarily highest in areas of greatest atrazine-use intensity. In fact, some of the Nation's highest use occurs in Iowa, Illinois, and Indiana, but soils in these areas tend to be poorly drained and, thus, artificial drainage by subsurface tile drains or trenches dewaters the agricultural fields. This practice tends to capture ground-water recharge and divert it to nearby streams. As a result, the detection of atrazine in ground water in these areas is less than it would otherwise be.

NAWQA estimates concentrations of dieldrin in fish in streams across the Nation**--** Although dieldrin residues in fish have declined substantially since the 1960s, NAWQA data and extrapolation results suggest that residues are still present in many streams across the country at levels sufficient to be of potential human health concern. This finding is consistent with the fact that, in 2004, there were 23 fish consumption advisories active for dieldrin in the United States, covering 606 river miles and 625 lake-acres in seven states. The highest modeled predicted concentrations of dieldrin were mostly concentrated in the Corn Belt, with scattered patches in Texas, the southeast, urbanized parts of the northeast, and California. Concentrations of dieldrin in fish can be estimated, in large part, by knowing historical agricultural use, urban termite use, forested land in the basin, and fish lipid content. Together, these four variables explain nearly 60 percent of the variability in concentrations measured in fish in streams across the Nation.

Regional and state models

NAWQA has completed extrapolations at more local scales; these models are used by local, State, and regional water managers to prioritize and plan protection strategies across broad regions. As indicated in the Washington and New Jersey examples, modeled findings can result in cost-effective savings by targeting monitoring to those streams and aquifers that are most vulnerable. Other examples show how modeled findings can be used to meet regulatory requirements, such as involving pesticide management plans (i.e. in Idaho), nutrient management strategies (in New England), and protecting drinking-water sources (see stories on nitrate in Southern New Jersey and arsenic in New England).

***State of Washington*—**The Washington State Department of Health, in concert with USGS, assessed the vulnerability of public water-supply wells to pesticide contamination based on statistical relations between levels of detection and geology, well characteristics, and land-use activities. NAWQA information on pesticide contamination enabled the health department to identify wells with low vulnerability to contamination and obtain waivers for quarterly monitoring required under the Federal Amendments to the Safe Drinking Water Act, 1996. By using the information to meet USEPA requirements for safe drinking water, Washington State was able to protect their drinking-water source while saving at least $6 million in costly additional monitoring. This was an annual savings of as much as $70 per household on small public supply systems that were granted full monitoring waivers.

***State of New Jersey* –** In collaboration with the New Jersey Department of Environmental Protection (NJDEP), the USGS collected data on contaminant occurrence in surface-water and ground-water resources, and related the results to geology, soils, land use, and other factors that affect vulnerability. Classification of almost 2,000 public supply wells according to their vulnerability to pesticides led to a substantial cost savings through monitoring waivers for water suppliers shown to be a low risk for contamination—specifically, the NJDEP estimated that because many wells and intakes were not vulnerable to contamination, waivers saved taxpayers at least $5.1 million annually for a one-time study cost of $1 million. The effort was done in response to the State Drinking-Water Act (SDWA) regulations (1996) that required the 626 large community water systems to monitor their 2,600 wells and 45 surface-water intakes quarterly for 23 pesticides. The monitoring would have increased consumers' water bills by $6.4 million each year.

***New England*–** USGS, in cooperation with the U.S. Environmental Protection Agency (USEPA) and New England Interstate Water Pollution Control Commission (NEIWPCC), developed a statistical model (referred to as SPARROW for SPAtially Referenced Regressions on Watershed Attributes) to understand how and where the quality of New England's waterways is affected by nitrogen and phosphorus contamination. The model estimates the levels of total nitrogen and total phosphorus and the sources of these nutrients in 42,000 stream reaches throughout New England. Modeled findings revealed, for example, that half of the nitrogen found in New England streams comes from the atmosphere. The model is used by water-resource managers within the NEIWPCC and USEPA to manage excess nutrients, which can stimulate damaging algal blooms downstream. During 2004, for example, the findings were incorporated in a regional long-term plan to reduce nitrogen entering Long Island Sound. USEPA Office of Research and Development uses modeled findings to help assess nitrogen inputs to coastal waters and to help explain results in their National Coastal Assessment in New England.

"The information generated by this modeling study is enormously valuable, and we're already using it to help us develop a long-term plan to reduce the amount of nitrogen that enters Long Island Sound." *(*Ronald Poltak, New England Interstate Water Pollution Control Commission, Summer 2004)

USGS also models arsenic in New England, in cooperation with the National Cancer Institute (NCI). The model is based on NAWQA findings for arsenic in ground water, as related to key factors controlling its occurrence, including geology, land use, and climate. Modeling results have helped the National Cancer Institute estimate lifetime arsenic exposure for individuals living in New England, including exposure from drinking-water sources.

Southeastern Idaho—As part of State Pesticide Management Plans for herbicides by the State Department of Agriculture, models and maps were developed by NAWQA to portray the potential for atrazine contamination in ground water in southeastern Idaho. Significant factors used to successfully predict atrazine concentrations in ground water were atrazine use, land use, precipitation, soil type, and depth to ground water.

Southern New Jersey—NAWQA scientists studied denitrification (conversion of nitrate to nitrogen gas) in southern New Jersey using a three dimensional model of ground-water flow that simulated the movement of nitrate through the shallow aquifer system to streams and public-supply wells. The model integrates hydrology with land use and nitrogen use over time and, therefore, is useful in predicting concentrations nitrate in unmeasured areas and into the future. Model simulations showed that concentrations of nitrate in streams and wells will not decline immediately, even with reductions in or stabilization of nitrogen use, primarily because of the amount of time required for water to move through the aquifer system and discharge to a stream or well. In fact, the model indicated that nitrate concentrations at 90-100 feet below land surface, which is a commonly completed depth of domestic wells in the Kirkwood-Cohansey aquifer in southern New Jersey, will continue to increase for several decades, and that ground water in areas of intensive nitrogen fertilizer use is likely to exceed the drinking-water standard for nitrate of 10 milligrams per liter by 2050. This model simulation assumes nitrate inputs remain unchanged from the year 2000. NAWQA modeled findings are used by water managers in the State of New Jersey to help manage nitrate in streams and ground water used for supply, to meet current and future projected use.

Looking at trends over the long term

"The NAWQA Program is unique in its capability to answer whether the Nation's water quality is improving. This is a fundamental long-term issue that policymakers are seeking to address."
(Claudia Copeland, Resources and Environmental Policy, Congressional Research Service, November 2004)

Water quality varies from season to season and from year to year and, therefore, long-term trends are sometimes difficult to distinguish from short-term fluctuations. It is too early to tell whether some types of chemical contamination are increasing or decreasing until NAWQA re-assessments are completed. Some trends and patterns, however, are evident from data collected over the last decade of NAWQA studies in 51 major river basins and aquifers. Specifically, selected results for nutrients in ground water, organochlorine pesticides in fish tissue and lake sediment, and for selected pesticides in stream water and ground water, provide initial insights.

NAWQA studies document the long-term presence of some contaminants, which in large part depends on their chemical properties. Not many, for example, would have anticipated the long-term persistence in some ground water of the fumigants 1,2-dibromomethane (EDB) and 1,2-dibromo-3-chloroproane (DBCP), nor the persistence in streams of certain organochlorine compounds, such as PCBs and the insecticides DDT, dieldrin, and chlordane. Concentrations of DDT and organochlorines have declined, but still persist at relatively elevated levels. For example, nationally, one or more organochlorine compounds were detected in sediment at about 60 and 80 percent of agricultural and urban stream sites, and concentrations exceeded sediment-quality guidelines at nearly 20 and 50 percent of those sites, respectively. Chlordane, in contrast to DDT, most commonly showed no significant change since 1970, and upward and downward trends were evenly split. Chlordane use in agriculture was discontinued in 1978, but its urban use for termite control exceeded its use in agriculture and continued until at least 1988, and use of existing stocks by homeowners was permitted after 1988 and was common in a 1990 survey. The regulation of organochlorine pesticides clearly has resulted in decreased contaminant levels; however, the continuing high levels of chlordane, the slow rate of decreasing trends for DDT, and the continuing concern for human exposure indicate that organochlorine pesticides will remain a concern for many years to come.

Studies also show that changes in water quality over time frequently are controlled by changes in chemical use and land-management practices. For example, concentrations of modern, short-lived pesticides such as acetochlor change as chemical use changes. Concentrations of acetochlor increased and those of alachlor decreased in many streams in the Upper Illinois River Basin and other parts of the Upper Midwest, where acetochlor partly replaced alachlor for weed control in corn and soybeans beginning in 1994. The changes in chemical use were reflected in stream quality, generally within 1 to 2 years. Contaminant concentrations also change with land-management practices. For example, conversion from rill (or "furrow") irrigation to sprinkler or drip irrigation in many parts of the Yakima River Basin, Washington since the early 1990s has reduced runoff from farm fields, resulting in decreases in suspended sediment, total phosphorus, dissolved nitrate, and organochlorine compounds in streams.

Ground water quality also responds to changes in chemical use, but usually more slowly than surface water. In many aquifer systems ground water moves at rates within the range of tens to hundreds of feet per year and it may take decades or more for water to move from areas of recharge to areas of discharge, such as streams or supply wells. Improvements in ground-water quality can thereby lag behind land-management changes by decades because of the slow rate of ground-water flow.

Long-term monitoring is critical to track the progress of our actions, such as reductions in chemical use and changes in land-management practices.

Delmarva Peninsula, Delaware, Maryland, and Virginia—NAWQA findings showed that nitrate in ground water used for domestic supply (about 45 feet below land surface) on the Delmarva Peninsula increased by an average of 2 milligrams per liter between 1988 and 2001. The median concentration in 2001 exceeded the USEPA drinking-water standard of 10 milligrams per liter. Increases in nitrate concentration most likely reflected an increased use of nitrogen fertilizers over the last 50 years. In contrast, the median concentration of nitrate in shallow ground water underlying agricultural areas (about 25 feet below land surface) did not change significantly over the same period, remaining below the drinking-water standard. Lower nitrate concentrations in the shallow groundwater may reflect positive effects of nutrient management practices on shallow ground-water quality, implemented by State and local water managers and farmers in many agricultural areas on the Delmarva Peninsula over the last 10 years. These improvements may not be apparent in the deeper parts of the aquifer because of the slow movement of ground water. Continued monitoring over the long term will show if trends continue and improvement from land-management practices occur.

"The Delmarva NAWQA study provides us with a timely report and assessment of water-quality trends for nutrients and pesticides in our ground-water and surface-water resources and reminds us all that much more needs to be done to protect and improve the water resources of Delaware." (Kevin C. Donnelly, Division of Water Resources, Delaware Department of Natural Resources and Environmental Control, June 2004, USGS Circular 1228)

Yakima River Basin, Central Washington— Previous NAWQA assessments (1988-1991) showed widespread detections of DDT and its breakdown products DDE and DDD (total DDT) in agricultural soils, stream water, suspended sediment, and fish in the Yakima River Basin in central Washington. Elevated concentrations of total DDT in bottom fish in the lower Yakima River were among the highest in the Nation. On the basis of these findings, the Washington Department of Health recommended that people eat no more than one meal per week of bottom fish from the lower Yakima River. Concentrations of total DDT in fish such as largescale suckers, smallmouth bass, and carp from the lower Yakima River decreased by about half from the late 1980s to 1998, but still exceeded guidelines for the protection of fish-eating wildlife. Decreases also were noted in stream water—total DDT was detected frequently in unfiltered water samples from the Yakima River in 1989, but was not detected in the Yakima River samples one decade later (1999). Reduced concentrations of total DDT in the Yakima River Basin were attributed primarily to the implementation of best-management practices (BMPs) by farmers throughout much of the basin. The BMPs help to limit runoff of sediment and sorbed DDT, including drip and sprinkler irrigation systems, cover crops and ground cover, sediment retention basins, and the use of PAM (polyacrylamide, which causes soil particles to adhere to one another.

Southwestern Florida—USGS works in partnership with the Florida Department of Agriculture and Consumer Services and the Southwest Florida Water Management District to evaluate trends in concentrations of agricultural chemicals in ground water. The herbicide bromacil was widely used in citrus production in central Florida until 1994 when its use in this region was replaced by alternative herbicides such as norflurazon and glyphosate. Its peak frequency of detection in ground water occurred in 1996 after which its occurrence declined. The decline in bromacil coincided with an increase in norflurazon. Bromacil continued to be detected in samples from 25 percent of the monitoring wells 10 years after its discontinuance for use in citrus production. Thus, changes in chemical-use practices may not be immediately reflected in ground-water quality and, in fact, pesticide occurrence in shallow ground water may actually increase for some time following such changes in chemical use. These results from the Florida citrus region help water managers track ground-water quality over time as a result of changing farming practices and pesticide applications, and to better understand the timing, variability, and process for transport of agricultural chemicals to the subsurface.

Town Lake, Austin Texas—Analysis of sediment cores (vertical tubes of mud) from reservoir and lake bottoms provides a quick snapshot of long-term water-quality changes that occur because of regulations and bans on chemical use. Runoff carries soil, debris, and attached contaminants to lakes and reservoirs, where they settle to the bottom; changes in water quality are thereby recorded in the successive layers of sediment. NAWQA studies of 42 reservoirs and lakes sampled in 20 rapidly urbanizing metropolitan areas from 1996-2001 show common patterns in quality, such as decreases in lead and increases in polycyclic aromatic hydrocarbons (PAHs) over several decades. For example, lead concentrations in Town Lake in Austin peaked in the late 1960s and then declined by about 70 percent, a direct response to the elimination of lead in gasoline. Concentrations of DDT generally followed its historical use in the United States, which peaked from the late 1950s to the mid-1960s and then declined substantially after its ban in 1972. Concentrations of PCBs, which were used primarily as insulation fluids in transformers and appliances peaked during the early 1960s and then declined by about 70 percent by 1998 (restrictions on PCBs were imposed in 1971). In contrast to trends in these regulated or banned contaminants, concentrations of total PAHs in Town Lake substantially increased. PAHs result from the burning of hydrocarbons. The increase in PAHs generally corresponded to roofing and increases in automobile use in the greater Austin area, which is evidence of the effect of non-industrial sources, such as vehicle emissions, road and tire wear, and engine oil leaks associated with growth on city fringes.

"USGS provides local, State, and Federal agencies with top quality data and accurate reporting that both the farming community and environmental community can trust. NAWQA's ability to look at water quality over the long term helps to evaluate the effectiveness of water-management decisions, conservation activities, and certain farming practices that are used to reduce sediment and runoff of agricultural nutrients and chemicals from fields, such as related to conservation tillage, buffer strips along streams, manure management systems, and improved irrigation systems. High quality and consistent monitoring of our natural resource is even more critical now as we begin to implement the 2002 Farm Bill, which authorizes over $39 billion for conservation—the highest funding in history for conservation programs that reduce soil erosion, preserve and restore wetlands, clean the air and water, and enhance wildlife habitat." (Jeff Loser, USDA Natural Resources Conservation Service, June 2004, USGS Circular 1237)

"The NAWQA program is generating water quality and ecological information that will be useful to the Oneida Environmental, Health and Safety Department in managing tribal water resources. As the Tribe engages in efforts to improve conditions of its watershed, NAWQA data and reports should serve as a reference against which future changes in water quality can be compared." (Patrick J. Pelky, Oneida Tribe of Indians of Wisconsin, Environmental, Health and Safety Department, 2001,USGS Circular 1156).

Supporting regulations, standards, and guidelines

NAWQA studies document the prevalence of low levels of pesticides in streams and ground water throughout the Nation. Concentrations were almost always below current USEPA drinking-water standards. Actual patterns of contamination, however, may differ from what is detected or regulated and, therefore, the risk to humans and the environment from low levels of exposure remains unclear. For example, current standards and guidelines do not account for contamination that occurs as mixtures of various parent compounds and breakdown products, or that is characterized by lengthy periods of low concentrations punctuated by brief, seasonal periods of higher concentrations. Specifically,

- *Seasonality*—In almost all 51 Study Units, contaminant exposure varied with seasons, with long periods of low or non-detectable concentrations punctuated by brief periods of much higher concentrations. Seasonal patterns were related primarily to the timing and amount of chemical use, the frequency and magnitude of runoff from rainstorms or snowmelt, and land-management practices, such as tillage.

- *Mixtures*—Streams and ground water in basins with significant agriculture or urban development almost always contained mixtures of VOCs, nutrients, pesticides, and their chemical breakdown products. Nationally, about 15 percent of samples collected from urban streams contained at least 10 VOCs. Similarly, about 23 percent of urban streams samples contained 10 or more pesticides. Possible cumulative effects on human and aquatic health from low concentrations of multiple compounds are unknown.

- *Breakdown products*—Breakdown products frequently were as common in the environment as the parent compounds. For example, atrazine, the most heavily used herbicide in the Nation, and its breakdown product deethylatrazine (DEA) were found together in about 75 percent of stream samples and about 40 percent of ground-water samples collected in agricultural areas across the Nation. Standards or guidelines to protect human health or aquatic life have not been established for breakdown products, yet they can be as toxic, or even more toxic, than parent compounds.

Effective water-resource management and watershed protection may require monitoring programs that analyze samples for breakdown products and multiple compounds, and that evaluate patterns related to seasons and storms when peak contaminant concentrations could possibly affect drinking-water supplies and critical life stages of aquatic organisms.

Cedar Rapids, Iowa— The NAWQA Program commonly detected elevated concentrations of nitrate and pesticides in the Cedar River and alluvium wells near Cedar Rapids, Iowa. The detections included pesticide breakdown products, which are mostly non-regulated and in some instances found at concentrations ten times the concentrations of parent compounds. On the basis of these findings, local officials in the city of Cedar Rapids, which obtains its water from the wells close to the Cedar River, has recommended monitoring and analysis of herbicide degradation products in city water supplies.

Potomac River, Washington D.C.— Sampling of nutrients and pesticides through a large storm event on the Potomac River in January 1996 showed that concentrations and total amounts of nutrients and atrazine can increase during localized large storms, sometimes with overwhelming effects on receiving waters, such as the Chesapeake Bay. In this case, concentrations of atrazine and other individual compounds exceeded USEPA drinking-water standards during and following the extreme storm event. Such information helped water suppliers better understand the role of short-term and seasonal events, which affected timing of withdrawals, mixing, and storage to most effectively deliver high quality water at a minimum cost.

Pesticide registration

Many contaminants and their breakdown products do not have drinking-water standards or guidelines. For example, only about half the pesticides (46 of the 83 measured compounds) and VOCs (27 of the 60 measured compounds) measured by the NAWQA Program have current USEPA standards.

USEPA Office of Pesticides relies on USGS for high-quality, nationally consistent monitoring data for pesticide registration and for their assessments of pesticide exposure. For example, NAWQA data help to guide USEPA's decisions on the commonly detected herbicides aldicarb, alachlor, and acetochlor, and the insecticides chlorpyrifos, diazinon, and carbofuran. In fact, the USEPA Office of Pesticides relies on USGS data to meet one of its performance goals, which states: "By 2010, detections of the 15 pesticides most frequently found in surface water in USGS 1994 NAWQA data will be reduced by 50 percent. Any new pesticides registered since 1996 found in USGS 2010 data for surface water will have a detection frequency no greater than 30 percent. By 2010, 50 percent of all pesticides with the potential to leach to ground water will be managed through labeling or other methods to prevent ground-water contamination.

"The NAWQA Program helps the U.S. Environmental Protection Agency (USEPA) implement the new pesticide law… Food Quality Protection Act (FQPA), passed in August 1996. USEPA has been required to factor potential exposures to pesticides through drinking water into already complex procedures used to set pesticide "tolerance levels" in foods. Incorporating potential drinking-water exposures into the pesticide tolerance-setting process has presented USEPA with many scientific challenges including: 1) What reliable data are available on pesticide concentrations in surface and ground water in the U.S.? How do these concentrations vary with location and time? 2) How can USEPA account for the considerable geographic variability in geology, hydrology, land use, and agronomic practices in estimating profiles of pesticide drinking water exposures in various regions across the U.S.? 3) What "real world" data are available to evaluate and improve computational models that USEPA uses to estimate pesticide drinking-water residues for new pesticides entering the market? 4) What types of surface- and ground-water monitoring should USEPA require pesticide makers to conduct after new pesticides (or significant changes in use areas or practices) are approved to verify that actual pesticide levels do not exceed those estimated through USEPA's screening procedures?

Building on many years of productive collaboration between USEPA and USGS, the NAWQA Program marshaled a wide range of its data and expertise to help USEPA address these and other questions. We do not have all of the answers yet by any means, but we in USEPA who are charged with implementing this part of the new FQPA are greatly impressed with the knowledge and expertise contributed by NAWQA Program scientists and managers to assist USEPA in addressing these questions. USEPA's Office of Pesticide Programs is a very satisfied "customer" of USGS and NAWQA water-resources programs." (Joseph J. Merenda, Office of Pesticide Programs, USEPA, 1998).

***State of Nevada*—**The Nevada Division of Agriculture, responsible for registering pesticides and protecting ground water, uses ground-water data collected by NAWQA in the Nevada Basin and Range to make decisions on registering pesticides. The agency historically used a network of deep supply wells for monitoring pesticides in agricultural areas of Nevada and no pesticides were detected by the State during 1993-1997 in these wells. However, the NAWQA Program reported the relatively frequent occurrence of pesticides, such as atrazine and simazine, on the basis of lower detection limits and shallower wells. These findings are incorporated in the Nevada registration process for pesticides.

"The NVBR NAWQA study detected pesticides in shallow ground water beneath urban and agricultural areas in Nevada. These results are being used by the Nevada Division of Agriculture to evaluate pesticide registrations in Nevada." (Charles Moses, Nevada Department of Business and Industry, Agricultural Division, 2001, USGS Circular 1170).

Improved understanding of drinking-water issues

"The NAWQA data are serving as a primary source of information for us in considering relative human exposure potential via water." (Joseph J. Merenda, Jr. Office of Science Coordination and Policy Office of Prevention, Pesticides, and Toxic Substances, USEPA, September 2003)

"The South-Central Texas study conducted by the National Water Quality (NAWQA) Program in Austin, Texas has provided this region of Texas new data and a valuable insight to current water quality in both surface and groundwater. This region is one of the fastest growing in population in Texas and in the nation, thus emphasizing the need for water quality data gathering, assessment and evaluation by federal water resource agencies such as USGS. The information provided to the San Antonio Water System during the past three years has been widely used in our utility. Additionally, the assistance and information provided by the USGS Water Resources Division in Texas is invaluable to providing safe drinking water sources for the second most populous state and one of the fastest growing in America." (Mike Mecke, San Antonio Water System, March 2001).

NAWQA information on the occurrence of more than 80 pesticides and degradation products and more than 60 VOCs in source water is used to set priorities for monitoring and managing contaminants in drinking-water supplies.

***Whatcom County, Washington*—**Elevated concentrations of 1,2-dichloropropane in ground water sampled by NAWQA scientists in the Puget Sound Basin renewed interest in determining the extent and source of drinking-water contamination in northern Whatcom County, Washington. The fumigant-derived compound was detected in ground water throughout the sampled area, sometimes at concentrations exceeding drinking-water standards. USGS works with Whatcom County to evaluate the occurrence and possible risk posed to the quality of drinking-water supplies by the use of 1,2-dichloropropane and other fumigants.

"In southwest Ohio, the USGS NAWQA Program has tapped an extraordinary number of research sources to perform a water-quality assessment of the Great and Little Miami River Basins. NAWQA is developing a picture of water quality [in the Great and Little Miami River Basins] that did not previously exist. This is a service for many constituents who rely on the Basins' water resources, including the dozens of public water suppliers who must produce safe drinking water and the towns and cities whose histories and futures are linked to the health of the rivers and the aquifer." (Jane Wittke, Water Quality Program, Ohio-Kentucky-Indiana Regional Council of Governments, June 2004, USGS Circular 1236)

NAWQA findings on contaminants and the key factors controlling their occurrence are used by local, State, and federal agencies to help reduce the uncertainty in estimating risks of human exposures.

***Agency for Toxic Substances and Disease Registry (ATSDR)*—**The ATSDR, which is responsible for evaluating the human health consequences of the public's exposure to hazardous chemicals, developed an "interaction profile" describing toxicological and adverse health effects data for a mixture of five hazardous substances commonly found in ground water. The interaction profile looks at the combined toxicity of atrazine, deethylatrazine, diazion, nitrate, and simazine. ATSDR selected these chemicals based on NAWQA findings for untreated groundwater samples from 1,255 rural wells and 242 public water-supply wells. The most frequently occurring four-chemical mixtures in these ground-water samples consisted of atrazine, simazine, deethylatrazine, and nitrate. Diazinon was the most frequently detected organophosphorus insecticide. None of the five substances has been classified as a carcinogen, but the ATSDR is concerned about possible additive effects or combinations that may form, such as atrazine in combination with nitrate to form n-nitrosoatrazine, which may be more damaging to DNA than atrazine.

***New Jersey*—**In cooperation with the New Jersey Department of Environmental Protection, the Oregon Health & Science University, and the U.S. Environmental Protection Agency, the NAWQA Program developed health-based screening levels for selected unregulated contaminants. During FY 2004, the screening levels were used to more comprehensively evaluate NAWQA's ground-water data in New Jersey in a human-health context, particularly for those contaminants with no existing Federal or State drinking-water standard or guidelines. Fourteen unregulated contaminants with new screening levels were detected, 10 of which were detected in ground-water resources used for drinking. Maximum detected concentrations for the contaminants generally were well below the new screening levels.

***New England*—**USGS scientists work with epidemiologists with the National Cancer Institute (NCI) to assess linkages between inorganic arsenic and bladder cancer in northern New England. NAWQA findings showed frequent detections of inorganic arsenic in wells drilled into the crystalline bedrock aquifer in northern New England, where deaths from bladder cancer have been elevated for the past 50 years. USGS data on arsenic and other metals, radionuclides, nutrients, and VOCs, as well as spatial information on geology, land use, and water use, contribute to an NCI database used to design NCI water-sampling protocols and a large-scale epidemiological study.

***Washington D.C.* –** NAWQA data and expertise on hydrology and water quality are used by the Potomac River Basin Drinking Water Source Protection Partnership to assess natural and human influences on water supplies within the Potomac River Basin This Partnership is a voluntary organization of water suppliers and local, State, and Federal agencies. NAWQA findings were used to help assess potential drinking-water issues related to contamination for the 3.6 million people in the Washington D.C. area where the Potomac River provides about 75 percent of the drinking water.

There is little scientific information on the occurrence of new pesticides, VOCs, and other synthetic contaminants, as well as microbial, viral, and pharmaceutical contaminants in drinking-water supplies. The NAWQA Program works collaboratively with other agencies to better understand these "emerging contaminants."

***Atlanta, Georgia*—**NAWQA scientists, in collaboration with the Center for Disease Control (CDC), monitor concentrations of pharmaceuticals and wastewater tracers in treated sewage effluent and raw and finished drinking water in the Chattahoochee Basin near Atlanta, GA. The findings were used to assess potential health issues related to these chemicals for the approximately 1.6 million people who receive their drinking water from the Chattahoochee River.

Delmarva Peninsula—NAWQA scientists on the Delmarva Peninsula work with USEPA and CDC to study antibiotic resistance of microbes in a watershed subject to heavy applications of poultry manure. Initial analysis of surface-water samples and sediment indicated that the microbial community is resistant to selected common veterinary antibiotics. Further monitoring, analysis, and collaboration will foster a better understanding of the issue and its implications for shallow drinking-water supplies.

***State of Pennsylvania*—**NAWQA scientists work with the Pennsylvania Department of Environmental Protection and USEPA to assess the occurrence and transport of viruses and fecal indicator bacteria in ground water used for non-community water supply. The results help state regulators and water suppliers make informed decisions about treatment options and screening techniques for viral contamination of ground water. The findings also support the State's Ground Water Rule, as required by USEPA, for disinfection of ground water used for public-water supplies. In addition, NAWQA scientists work with the Pennsylvania Department of Environmental Protection to assess factors contributing to the reported high incidence of bacteria, total coliform, and *E. coli* in ground water used for domestic supply.

The NAWQA Program measures compounds at very low concentrations, often 10 to 100 times lower than Federal or State standards and health advisories. Detection of compounds by NAWQA studies, therefore, does not necessarily translate to risks to human health or aquatic life. However, the findings are useful for identifying emerging issues and tracking contaminant concentrations over time. The prevalence of MTBE in shallow ground water is one such issue, identified by NAWQA studies in the 1990s. MTBE had been hailed in the 1970s as a compound that could help improve air quality in many urban areas by oxygenating gasoline and allowing it to burn cleaner. MTBE's high solubility in water and persistence in the subsurface were not considered. As a result, we are now confronted with the unintended consequence of widespread, albeit low, MTBE contamination in much of the shallow ground water in U.S. urban areas. In fact, MTBE was detected in more than 50 percent of shallow wells sampled in urban areas.

At the request of USEPA and the White House Office of Science and Technology Policy, scientists with the NAWQA Program participated in an interagency assessment of the scientific basis and efficacy of the winter oxygenated gasoline program. This program mandates that compounds, such as MTBE, be added to gasoline in selected metropolitan areas to reduce the amount of atmospheric carbon monoxide in the winter. As part of the interagency assessment, NAWQA scientists reported on water-quality issues arising from the use of fuel oxygenates, including (1) occurrence of these compounds in drinking water, storm water, and streams; (2) environmental behavior and fate of fuel oxygenates (such as potential for biodegradation and remediation); and (3) recommendations on the types of monitoring and studies needed for improved exposure and risk assessment. On the basis of this input, along with studies and research by other federal agencies, universities, and the private sector, USEPA recommended reducing or replacing MTBE with other oxygenates.

A preliminary analysis by USGS, in collaboration with the Metropolitan Water District of Southern California and Oregon Graduate Institute, showed potential sources of MTBE contamination near large number of community water supplies. Specifically, findings from about 36,000 community water supplies indicate that approximately 9,000 community water supply wells in 31 states are less than a mile from a leaking underground storage tank. Not all of these leaking tanks will be a significant source of MTBE to ground water and to the wells. However, the large number (9,000) suggests that the actual number of community water supply wells that may be affected should be identified.

New England—USGS conducted a study in 12 states in the Northeast in cooperation with USEPA to better understand MTBE and other VOCs in drinking water supplied by more than 2,000 community-water systems. The study, including more than 21,000 samples collected during 1993-1998, found that MTBE was reported in nearly 9 percent of the community-water systems for which MTBE data were available (about 1,200). Detections were five times more likely in areas where MTBE-enriched, oxygenated or reformulated gasoline has been used. Chloroform was the most frequently detected VOC in the drinking water, reported in nearly 40 percent of the community water systems.

State of Iowa—NAWQA findings on the prevalence of MTBE in ground water beneath urban areas were used in the development of state legislation and to design a new water-quality network. The legislation (House File 772) (1) limits the amount of MTBE in motor vehicle fuels to less than 2 percent by volume; (2) established an interim committee to "study issues relating to the sale, use, and health and environmental effects of oxygenate enhancers contained in motor vehicle fuel, including but not limited to ethanol and methyl tertiary butyl ether"; and, (3) requires analysis of MTBE in water and soil at leaking underground storage tank sites. In addition, as a result of NAWQA findings, Iowa began a statewide study to determine the impact of MTBE on municipal and public-water supplies by sampling all systems that use ground water as a source of drinking water.

State of Pennsylvania—The Pennsylvania Department of Environmental Protection works with USGS to assess the prevalence of MTBE in ground water and its potential to contaminate public drinking-water supplies. Through the partnership, consistent and quality-assured data are compiled to provide a qualitative vulnerability rating for MTBE based on different hydrogeologic settings throughout the State of Pennsylvania. The results help to prioritize areas where MTBE should be assessed; where public-supply wells should be tested; and where gasoline storage tanks should be inspected.

Contributing to State and local requirements

Source-water protection strategies and statewide management plans

"The NAWQA Program has filled a tremendous void in the pesticide data that the State of Alabama must acquire in the development of the USEPA-mandated State Pesticide Management Plans. The scope of the data collected has made the decision-making process of writing the plan simpler because actual NAWQA data are used to make important determinations and the plan can target the areas of greatest importance." (Tony Cofer, Pesticide Division, Alabama Department of Agriculture and Industries, June 2004, USGS Circular 1231)

States, Tribes, and localities use NAWQA information to develop source-water protection strategies and statewide management plans, such as for pesticides, nutrients, and MTBE. Specifically, state environmental and natural resource agencies prioritize streams and ground-water areas for assessment of these constituents on the basis of vulnerability concepts, contaminant occurrence data, and quality-assurance protocols of the NAWQA Program.

State of New Jersey—NAWQA data on organic compounds are used heavily in New Jersey's source-water assessment. USGS and the New Jersey Department of Environmental Protection are developing models to assess the vulnerability of public water supplies (including surface-water intakes and ground-water community and non-community wells) in the State to contamination by regulated compounds.

State of New York—NAWQA findings in the Hudson River Basin represented a broader array of analyses using lower detection limits than data previously available to the State. The New York State Department of Environmental Conservation applies the NAWQA pesticide information and protocols in its statewide pesticide monitoring, as required under the New York State Pesticide Reporting Law, to improve decisions regarding pesticide registration (Environmental Conservation Law Section 33-0714). A part of the monitoring program investigates the occurrence of pesticides and their breakdown products in public-water supply reservoirs, including the New York City network, the Finger Lakes-Great Lakes network, and the western New York reservoir network. Collaborative efforts with USGS were expanded beyond the Hudson River Basin to other parts of the State, sparked by public concerns over pesticides in New York State waters and their possible relation to the incidence of breast cancer. The project, which is based largely on NAWQA protocols and sampling, has resulted in a better understanding of the occurrence of pesticides throughout the state, such as the occurrence of dieldrin and other organochlorine compounds in the sole source aquifer on Long Island.

"The Hudson River Basin NAWQA program has provided the Department with crucial information and a solid monitoring foundation to create our own statewide pesticide-monitoring program. It is our expectation that expansion of the NAWQA work to include other important areas of New York State will enable us to successfully meet all State and Federal monitoring requirements and provide the Department with the data we need to make responsible pesticide registration decisions." (Larry Rosenmann, New York State Department of Environmental Conservation, 2001,USGS Circular 1165).

State of Kansas—NAWQA findings on elevated concentrations of atrazine (frequently approaching or exceeding the USEPA drinking-water standard) in water-supply reservoirs in the Lower Kansas River Basin were used by the Kansas State Board of Agriculture as the basis for establishing a pesticide management area in northern Kansas (Delaware River Basin). Within this management area, the State of

Kansas called for both voluntary and mandatory restrictions on pesticide usage on cropland to improve water quality. The management area was the first in the Nation to focus on reducing atrazine in runoff to streams and reservoirs.

***Menominee Tribe of Wisconsin*—**The Menominee Tribe of Wisconsin works with NAWQA personnel in sampling mercury at a relatively pristine, undeveloped site in the Western Lake Michigan Basins in Wisconsin. The tribe used the data in their development of water-quality management and monitoring programs.

***State of California*—**USGS works with the California State Water Resources Control Board and Department of Health Services to assess the vulnerability of public-supply wells to contamination. The State uses USGS ground-water-age-dating analyses as one indicator of vulnerability. In addition, on the basis of NAWQA findings on the occurrence of industry-related and petroleum-based chemicals in ground water, the State has included the collection and analysis of VOCs in their vulnerability assessment. More than 200 wells have been sampled in southern California.

***State of Washington*—**The Washington State Department of Ecology created a Ground Water Management Area to protect ground water from nitrate contamination. The management area covers Grant, Franklin, and Adams counties, located in an intensive agricultural region of the Central Columbia Plateau. NAWQA information and communication of those findings in the USGS publication "Nitrate Concentrations in Ground Water of the Central Columbia Plateau" provided the scientific basis for implementing the management area. As follow-up to the NAWQA findings, USGS works with the Department of Ecology to (1) identify areas with lower nitrate concentrations, which could potentially serve as sources of future drinking-water supplies, (2) statistically correlate nitrate concentrations with natural features and human activities to better assess vulnerability; and, (3) design a long-term monitoring strategy for assessment of changes in nitrate concentrations over time.

"I coordinate the Upper Mississippi River Source Water Protection Initiative, an effort that will lead to the development of source-water protection plans for public water suppliers within the upper Mississippi River basin. The water quality data that have been generated and documented through NAWQA will figure prominently in the preparation of these plans. The information on certain contaminant levels in various settings within the basin, and the information describing the sources of contaminants provide documentation and solid rationale for identifying source water protection strategies, priorities, and protection measures for public water suppliers. In my opinion, more than any single information source, the Upper Mississippi River NAWQA provides an extremely valuable substantive basis for source water protection in the Upper Mississippi River basin." (Mr. David Brostrom, Upper Mississippi River Source Water Protection Initiative, March 2001).

Assessments of beneficial uses and impaired waters (Total Maximum Daily Loads)

Consistent and comparable monitoring information is needed to effectively assess beneficial uses (as required in USEPA 305(b) reporting) and impaired waters (as required in USEPA 303(d) reporting), and to develop Total Maximum Discharge Loads (TMDLs). NAWQA information on the occurrence, sources, and transport of contaminants is used by States and Tribes to meet these requirements.

***Wind River Environmental Quality Commission of the Shoshone and Arapahoe Tribes, Wyoming*—**USGS assists the tribal Wind River Environmental Quality Commission of the Shoshone and Arapahoe Tribes in sampling large river sites. NAWQA protocols are used for selected water-column and aquatic ecological sampling. The Commission uses this information in their State Assessment 305(b) report and to make management decisions on the surface-water resources.

State of Missouri—The Missouri Department of Natural Resources has incorporated NAWQA stream-quality data into their database for monitoring compliance with USEPA 305(b) water-quality standards. The Department uses the data to describe attainment of beneficial uses, to identify and prioritize problems, to help develop Total Maximum Discharge Loads (TMDLs), and to assist in overall natural resource management.

State of New Jersey—The New Jersey Department of Environmental Protection use NAWQA findings in the preparation of their State Assessment 305(b) reports (beginning in 2000). Specifically, NAWQA information is used to report (1) the long-term nature of nitrate contamination; (2) improvements in stream conditions and fish communities in northern New Jersey due to improvements in waste water treatment; (3) relations between impaired biological communities in urban streams and impervious surfaces; and, (4) use of synthetic chemicals on biological health.

An understanding of critical factors controlling sources and transport has proved critical in the accurate establishment of TMDLs in selected stream segments across the Nation.

***State of Ohio*—**NAWQA findings showed elevated loadings of insecticides, polycyclic aromatic hydrocarbons (PAHs) and heavy metals in urban streams and rivers in the Great and Little Miami River Basins. The study was used by Ohio EPA in FY 2004 to assign with greater confidence the causes and sources of pollution to impaired waters appearing on their listing of impaired waters (USEPA 303(d) listing). Results were timely with respect to several on-going Ohio EPA TMDL studies, particularly for Big Darby Creek, which was designated by American Rivers as one of the ten most imperiled rivers in the Nation because of suburban development.

Scientific findings on nutrients and aquatic communities also supplied critical information for Ohio Environmental Protection Agency's Total Maximum Daily Load (TMDL) effort in the Stillwater River Basin in Ohio and continue to provide valuable data for future TMDLs in other sub-basins of the Great Miami River.

"Data from the NAWQA [Program] supplied critical information for Ohio EPA's Total Maximum Daily Load (TMDL) effort in the Stillwater River Basin, and will continue to provide valuable data for future TMDLs in other sub-basins of the Great Miami River. Additionally, the NAWQA study has helped further our understanding of linkages between nutrients, land use, and impairment of aquatic life. The USGS has also been particularly generous in sharing scientific expertise developed by NAWQA with Ohio EPA, especially their expertise in sampling algal communities." (Robert Miltner, Ohio Environmental Protection Agency, June 2004, USGS Circular 1229)

***State of Oregon*—**Data on atmospheric mercury concentrations and loads to the Willamette Basin, Oregon were incorporated in an interim basin-wide, mercury TMDL by the Oregon Department of Environmental Quality (ODEQ). These atmospheric data are unique in that they are the first available for Oregon. NAWQA sampling efforts in the Willamette Basin continue to provide information to the ODEQ on mercury sources (especially in urban basins), mercury methylation rates, seasonal variability of mercury concentrations in streams, and bioaccumulation of mercury within the aquatic food web—all of which have been identified as areas needing additional research as ODEQ moves toward development of a final TMDL to be issued in 2009.

State of North Carolina—An improved understanding of sources and transport via ground-water discharge has proved critical for accurate setting of TMDLs in North Carolina. NAWQA findings in the Albemarle-Pamlico Sound, North Carolina highlighted relatively significant sources of elevated phosphorus in discharging ground water to the Tar and Neuse Rivers, which likely originates from naturally occurring phosphate minerals in deep Cretaceous-age aquifer sands. The results are critical to fully account for all contributing phosphorus sources.

"As the TMDL (Total Maximum Discharge Loads) Coordinator for the Minnesota Pollution Control Agency (MPCA), the UMIS NAWQA study has been very valuable. The approach focuses on watershed health and the types of stressors that are important to the MPCA as we do our basin planning and TMDL restoration studies. NAWQA was flexible enough to include the St. Croix basin, further strengthening an already very active multi-state and federal study effort." (Dr. Howard Markus, Minnesota Pollution Control Agency, March 2001).

"Information provided by the Yellowstone NAWQA project has been very useful to our program. The Yellowstone River Basin periphyton study results are a fundamental aspect of Montana's Department of Environmental Quality's fish and aquatic use impairment determinations and a foundation for nutrient total maximum daily loads (TMDL) development. NAWQA Powder River data have been a critical part of trend analysis work. Without that data, we *would have had very little recent information."* (Pat Newby, Montana Department of Environmental Quality, June 2004, USGS Circular 1234)

State of Maryland—NAWQA findings on the movement of nutrients and sediment to surface water in the Potomac River Basin are incorporated in a watershed model that is used to evaluate TMDLs for nutrients and sediment in several tributaries and the main stem of the Potomac River.

State of Mississippi—The Mississippi Department of Environmental Quality (DEQ) works with NAWQA to determine biological indicators of water quality in streams in the Yazoo River Basin. NAWQA findings on water transport and water quality in the alluvial plain of the Yazoo River Basin serve as the foundation for a cooperative project with the DEQ to evaluate streams in the alluvial plan in support of Mississippi's 305(b) process and development of TMDLs.

State of Texas—USGS works with the Texas Natural Resource Conservation Commission and City of Fort Worth to better understand the occurrence, transport, and effects of legacy pollutants, such as DDT and PCBs, in urban streams and lakes in Fort Worth, Texas. The information is used by the State of Texas in their TMDL assessments of impaired urban waters. USGS is leading a comprehensive sediment coring and suspended-sediment sampling program, which is designed to determine if, and at what rates, these pollutants enter urban streams and lakes and how long it could take for these pollutants to naturally attenuate to safe levels.

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Minneapolis, Minnesota—NAWQA findings for Shingle Creek and other urban streams near the greater Minneapolis metropolitan area indicated a widespread chloride problem with significant implications regarding TMDL "course-of-actions." Chemical and biology samples collected by USGS in Shingle and Nine Mile creeks and 13 other major streams in the metropolitan area indicated clear relations between chloride concentrations and impervious surfaces and snowmelt (which is highly suggestive of salt applications for road-deicing). The data, placed in context with other NAWQA samples in urban streams throughout the Nation, showed that chloride concentrations significantly increase with increasing development. Prior to these USGS findings, the

Shingle Creek Watershed Management Commission believed that chloride in Shingle Creek was a local, and solely a stockpile, issue. On the basis of USGS chloride results, the Commission recommended a metropolitan-wide approach to manage road salt use and to explore alternatives to sodium chloride (such as calcium magnesium acetate, which is higher in cost, but has a slower activation rate). The improved assessment of chloride sources led to improved strategies needed to meet Minnesota standards.

Nutrient enrichment and criteria

Nuisance plant growth is noted in streams across the nation because of elevated concentrations of nutrients. In fact, concentrations of phosphorus exceeded the USEPA desired goal for phosphorus for preventing nuisance plant growth in streams (0.1 parts per million) in about 75 percent of agricultural and urban streams sampled by the NAWQA Program. It is difficult and premature, however, to attempt a national summary of the effects of eutrophication because methodologies are limited for deriving criteria based only on nutrient concentrations. In recognition of these limitations, USEPA, in collaboration with USGS and other federal agencies, and state agencies, is developing a strategy to evaluate aquatic plant growth and to develop an understanding of stream nutrient dynamics, stream habitat (including shading and temperature), turbidity, and algal-growth processes.

"We will work with states and tribes to develop a methodology for deriving criteria, as well as developing criteria where data are available, for nitrogen and phosphorus runoff for lakes, rivers, and estuaries by the year 2000. We intend to develop such criteria on a regional basis using scientifically defensible data and analysis of nutrients, such as those available from the USGS. (Robert Cantilli, USEPA, USGS Circular 1225, 1999).

***State of Louisiana*—**USGS works with the Louisiana Department of Environmental Quality to develop nutrient criteria using NAWQA information on *chlorophyll a* in the Acadian-Pontchartrain Basins. According to Louisiana Department officials, "The largest, most consistent source of *chlorophyll a* data for Louisiana comes from NAWQA sites."

***State of Indiana*—**NAWQA scientists, in collaboration with the Indiana Department of Environmental Management (IDEM), monitor seasonal and annual trends of nutrient and algal concentrations and their potential effects on the biotic community. NAWQA findings were included in the USEPA approved State of Indiana Nutrient Criteria Plan.

"The work that USGS is doing at NAWQA sites in Indiana provides a major contribution to Indiana's plan to develop nutrient criteria for the State. Indiana, like many States, is opting to try to develop nutrient criteria based on "cause and effect" relationships. NAWQA data provide valuable information on seasonal and annual trends, fate and transport of nutrients, and relations between biological, chemical, and physical data—all of which help to define cause-and-effect relationships between nutrients, algal responses, and biological condition." (Denny Clark, Indiana Department of Environmental Management, October 2004)

***State of Oklahoma*—**The Oklahoma Water Resources Board recommended a limit of 0.037 milligrams per liter of total phosphorus for six of Oklahoma's highest-quality waterways. The 0.037 value came from a NAWQA Nutrient National Synthesis Report published in the Journal of the American Water Resources Association entitled "Nutrient Concentrations and Yield in Undeveloped Stream Basins of the United States" by, G.M. Clark, D.K. Mueller, and M.A. Mast. The streams drain areas of Arkansas heavily affected by poultry farming and as a result, the phosphorus limit faces stiff opposition from Arkansas.

"Water quality data and analysis for the Upper Illinois River Basin NAWQA study will be useful in developing Illinois nutrient standards and prioritizing the development of standards for other pollutants." (Richard Lanyon, Research and Development, Metropolitan Water Reclamation District of Greater Chicago, June 2004, USGS Circular 1230)

St. Croix National Scenic Riverway, Minnesota—The St. Croix River Water Resources Planning Team, which is a multi-state-Federal cooperative organization, use NAWQA data to implement a protection strategy for the St Croix River in effort to reverse ecological degradation. In 2004, the Team announced a goal for a 20-percent reduction in phosphorus loading to the watershed. This recommendation was in large part based on NAWQA findings on nutrient loadings from tributaries.

"We are very fortunate to have the St. Croix National Scenic Riverway included in the NAWQA Program. The work done through NAWQA has proven to be invaluable and has provided a firm foundation and the momentum for additional studies. We have gained tremendous *benefits from our association with NAWQA."* (Randy Ferrin, St. Croix River Water Resources Planning Team, National Park Service October 2004)

"The St. Croix National Scenic Riverway (NSR) was established in 1968 under the National Wild and Scenic Rivers Act. In the early 1990's continued development and usage of the St. Croix River concerned water resource managers about the impact on water quality. Research from the NAWQA Program provided evidence that nutrient loading from the tributaries was increasing the rate of eutrophication in Lake St. Croix, a sink of the St. Croix River Basin. In response to these threats, a cooperative agreement was signed in 1993 by the National Park Service, the Minnesota Department of Natural Resources, the Wisconsin Department of Natural Resources, and the Minnesota Pollution Control Agency. To date, the partnership that was formed (St. Croix Basin Water Resources Planning Team) has relied heavily on data from NAWQA to implement a protection strategy for the St. Croix River." (Pam Davis, St. Croix Basin Water Resource Planning Team, March 2001).

Stream protection and restoration

Activities associated with agriculture, urban areas, and (or) forests can affect stream-habitat conditions and fish, aquatic invertebrate, and algal communities. Degraded water and sediment, and physical alterations to streams that result in changes in stream flow, temperature, and channel morphology, commonly result in degraded stream habitat, reduced biological diversity, and an increase in the number of species tolerant of disturbance, such as worms, midges, and omnivorous fish communities. The most profound effects can be seen in urbanizing areas.

NAWQA stream-ecology studies in the metropolitan areas of Anchorage, Birmingham, Boston, Chicago, Dayton-Cincinnati, Los Angeles, Philadelphia-Trenton, and Salt Lake City show that changes in aquatic communities are noticeable at low levels of urbanization within a basin. For example, in Anchorage, changes in aquatic communities are evident when watersheds reach about 5 percent impervious area, which in Anchorage correlates with a population density as low as 125 to 250 people per square mile. Findings also indicate that physical characteristics are altered with increasing urbanization, which can greatly affect aquatic communities. Specifically, increased residential and commercial development and road density often are associated with less tree canopy for shading, increased water temperatures, and more impervious surfaces, storm drains, and other artificial controls, all of which can increase the amount and rate of runoff during storms. As a result, increases in the magnitude and volume of peak stream flows can destroy fish-spawning beds, remove woody debris, transport large amounts of sediment, and remove natural substrates. These physical alterations are not typically tolerated by sensitive aquatic communities. Water temperatures often are increased in urban streams as a result of runoff flowing over impervious areas, such as parking lots and buildings. Many aquatic organisms can survive only within a narrow temperature range.

"The Mississippi River is one of the great rivers of the world and a vital component of the ecology and economy of Minnesota. We have consistently relied upon the NAWQA research on the Upper Mississippi for scientific data from which to assess the river's health. This is high quality data that play a key role in shaping river management policies and investment priorities." (Mr. Whitney Clark, Friends of the Mississippi River, March 2001).

"The NAWQA study of urbanization and stream quality drew comparable conclusions to an Ohio EPA state-wide study of effects from urbanization, confirming the importance of maintaining riparian buffers and stream physical habitat. The finding has clear implications in drawing guidelines for suburban development. The NAWQA study was also able to confirm what Ohio EPA could only conclude inferentially, that a significant part of the cause of poor biological quality in urbanized catchments is due to loadings of contaminants. These findings are important because many researchers focus mainly on the consequences of hydrologic alteration affected by impervious surfaces and ignore water quality. The USGS NAWQA program helps Ohio EPA make informed water-resource management decisions by providing information from independent water-quality studies and advancing the science of water-quality monitoring, and through collaborative studies and sharing of technical expertise for the study of water-quality problems." (Bob Miltner, Ohio Environmental Protection Agency, May 2004)

"Alaska's social and economic fabric is inextricably bound to the health of our salmon habitat and water quality. The NAWQA Program has played a critical role in helping policy makers, businesses and citizens better understand the complexities of our watersheds, and as a result, we now have better tools to manage our salmon and water resources for future generations." (Bob Shavelson, Cook Inlet Keeper, Alaska, June 2004, USGS Circular 1240)

"Properly balancing competing water-resource demands while conserving our significant fish and wildlife resources for future generations is one of the most critical environmental management issues facing the Service today. The NAWQA Program provides an objective scientific foundation to assist resource agencies charged with making difficult management decisions. It synthesizes surface-water, ground-water, and biological data in an accessible and understandable way for a wide variety of readers. We find the NAWQA Program to be a valuable resource to our agency." *(*Larry E. Goldman, U.S. Fish and Wildlife Service, June 2004, USGS Circular 1231)

Information on the effects of urbanization on aquatic life can help planners and decision makers to design and prioritize cost-effective strategies for stream protection and restoration (such as managing chemical use, controlling storm runoff, or restoring riparian habitat).

U.S. Environmental Protection Agency— The USEPA Office of Pesticides use NAWQA's extensive and nationally consistent pesticide data to assess the presence of toxic chemicals in areas where fish protected under the Endangered Species Act are present.

***State of Nebraska*—**Continuous water-quality monitoring and monthly sampling by NAWQA at the Platte River near Louisville were used by the U.S. Fish and Wildlife Service in 2004 to help determine habitat requirements for re-establishment of the endangered pallid sturgeon fish in the Platte River. The Fish and Wildlife Service also used NAWQA monthly-sampling results as baseline information to assess potential exposure of sturgeon to endocrine-disrupting compounds.

State of New Jersey—On the basis of NAWQA findings in the Long Island-New Jersey Coastal Drainages, USGS works with the New Jersey Department of Environmental Protection to evaluate the effects of land use, hydrology, and pollution sources on biological indicators, including benthic macroinvertebrates and fish communities. Findings from the joint project are used to develop realistic stream management and restoration goals for urbanized streams.

State of North Carolina—NAWQA findings are used by the North Carolina Department of Environment and Natural Resources to help control excessive nutrients and resulting algal blooms, fish kills, and *Pfiesteria* incidents in the Neuse and Tar-Pamlico Rivers. For example, the findings led to the implementation of buffers in the Neuse River, which proved to effectively reduce nutrient runoff to the surface water. In addition, NAWQA research on the role of organic matter in streambed sediment in removing nitrate from ground water in some areas of the Coastal Plain has allowed the State to prioritize its efforts in streams where elevated nitrate is not as easily removed under natural conditions.

***Upper Midwest*—**Biological data collected by NAWQA study units in the Upper Mississippi River Basin, Eastern Iowa River Basin, and Lower and Upper Illinois River Basins were used by the Nature Conservancy and NatureServe to set biological priorities in the Upper Midwest. NAWQA data were used by these two non-profit organizations to identify 47 sites in 7 States as the highest priority areas for conservation in the region and 22 significant areas for protection of freshwater biodiversity.

***State of Utah*—**The NAWQA sampling strategy of integrating water chemistry, biology, and physical habitat as "multiple lines of evidence" was used in by a multi-agency taskforce that includes the U.S. Fish and Wildlife Service and Utah Department of Environmental Quality to assist in management of trace element contaminants in water, sediment, invertebrates, and fish resulting from mining operations.

***State of California*—**Excessive mercury concentrations in water systems results in environmental concerns and identifying the source of the mercury is an important step in mitigating impacts. Unlike other areas of the United States where the atmosphere is generally the main source of mercury contamination, the major source of elevated mercury concentrations in the Sacramento River Basin has been from mercury mining and from the use of mercury in gold mining during the 19th century. Mining has resulted in streambed sediments that contain large mercury deposits that can contaminate water and fish. A recent USGS study found that colloidal suspended particulate matter plays an important role in downriver mercury transport, with greatest impact occurring during high flow or runoff events. The data provide water-resources managers with an improved understanding of the source and speciation of mercury occurrence in the Sacramento River.

State of Colorado—In the French Gulch watershed near Breckenridge, Colorado, metal mining has greatly impacted the watershed. NAWQA findings in the Upper Colorado River Basin on trace elements, streambed and suspended sediment, fish tissue, and macroinvertebrates helped a coalition of local agencies and organizations (French Gulch Remediation Opportunity Group) to determine realistic options for remediation. The coalition also gained support for continued monitoring at NAWQA sites as the remediation strategies were gradually implemented.

Urbanization and increased recreation in and around the Town of Vail, Colorado have impacted water quality in the Gore Creek watershed. Local water managers strive to maintain their gold-medal fisheries and, therefore, have conducted a mini-"NAWQA assessment" of the entire Gore Creek watershed using NAWQA protocols and sampling design. Integrated analyses of macroinvertebrates, fish, algae, surface- and ground-water chemistry, and bed-sediment chemistry have been completed. The NAWQA approach has helped the watershed group to understand the current health of the ecosystem, to make land-use decisions, such as those related to riparian buffer needs, and to implement best-management practices.

***Houston-Galveston, Texas*—**As a follow-up to the NAWQA study in the Trinity River Basin, USGS has worked with the Houston-Galveston Area Council to assess the status of biological communities in the nontidal urban streams of the San Jacinto River Basin, in and near the greater Houston metropolitan area. The study uses biological and stream habitat assessment methods established by the NAWQA Program to allow direct comparisons of the State's impaired waters (listed as USEPA 303(d) segments) with regional stream reference conditions.

Fish consumption advisories

Potentially toxic compounds, such as DDT, chlordane, dieldrin, polychlorinated biphenyls (PCBs), and mercury, were commonly detected in fish in sampled streams, often at higher concentrations than in the sediment. Nationally, for example, one or more organochlorine compounds (including organochlorine pesticides and PCBS) were detected in about 95 percent of whole-fish samples collected at urban sites. Concentrations of organochlorine compounds in fish tissue exceeded guidelines to protect wildlife at nearly 75 percent of urban sties.

NAWQA information on organochlorine compounds and trace elements in fish tissue is used by states to evaluate and establish fish consumption advisories.

***State of South Carolina*—**NAWQA provided sound data on mercury concentrations to the South Carolina Department of Health and Environmental Control (SCDHEC) that helped explain elevated mercury in fish and the large number of fish consumption advisories in rivers and streams in and around the Santee River Basin. Comparisons to other NAWQA studies across the Nation showed that this basin has one of the highest rates of conversion of inorganic mercury to its more toxic form, methylmercury, which is the form readily available for uptake by fish and other aquatic communities. The findings were used by the SCDHEC and the National Park Service, in partnership with USGS, to assess natural factors controlling the mercury conversion, such as related to sediment microbial communities. The analysis is used to guide the State's continued management of stream health and fish advisories.

***State of Washington*—** The Washington Department of Ecology issued fish-consumption advisories for rainbow trout and mountain whitefish caught in the Spokane River from Upriver Dam, Washington to the Idaho state line because of elevated levels of PCBs and lead. The first advisory was issued for lead in August 2000 following the release of NAWQA information on lead and other heavy metals. A second advisory was released in early 2001 for PCBs following a joint study by the State and USGS that looked at PCB occurrence and heavy metals downstream from Idaho's historic mining activities.

NAWQA scientists, participating on a multi-agency team studying Lake Roosevelt, a popular fishing area in Washington State, collected several species of fish to evaluate mercury contamination. The results led to a site-specific health advisory for mercury by the Washington State Department of Health for consumption of walleye because possible adverse health effects from mercury.

In the Yakima River Basin, the insecticide DDT was detected at elevated concentrations in water, streambed sediment, and fish tissue. These NAWQA findings suggested a potential health concern, especially to the local population of Native Americans who rely on fish as a major source of food, and a continued threat to fish-eating birds. The Washington State Department of Health recommended that people eat no more than one meal per week of bottom fish from the lower Yakima River.

"The Washington State Department of Health has determined that a human-health impact analysis should be conducted to determine if concentrations of DDT in fish in the Yakima River Basin pose a threat to human health. This determination was made on the basis of concentrations of total DDT reported from the analysis of fish tissues in the National Water-Quality Assessment study and results of preliminary risk-assessment calculations." (Glen Patrick, Washington State Department of Health, 2001, USGS Circular 1090).

State of New York**—**NAWQA findings documented the occurrence of PCBs in the Mohawk River in the vicinity of Utica and Little Falls, New York. These results contributed to decisions by the New York State Department of Health to issue fish consumption advisories on carp and selected game fishes, including largemouth bass and tiger muskellunge.

State of Pennsylvania—The Pennsylvania Department of Environmental Protection uses NAWQA data collected in game species to re-evaluate fish advisories on the Schuylkill and Delaware Rivers. PCB, chlordane, DDT, and dieldrin were the most frequently detected organochlorine compounds in fish tissue from 30 sites sampled throughout the Delaware River Basin. Among the four sites at which smallmouth bass fillets were analyzed for organochlorine compounds, three exceeded the Great Lakes consumption advisory level for PCBs.

State of Texas**—**High levels of PCBs detected in fish in the Donna Canal in south Texas in the early 1990s led to a ban on possession and consumption of fish. Subsequent extensive sampling studies by the State of Texas continued to reveal high levels in fish but no information on potential sources. The Texas Natural Resource Conservation Commission approached the NAWQA Program in 1998 and requested suspended-sediment chemistry and coring methods to locate the PCB source. USGS sampling narrowed the potential source to a 90-meter stretch along the approximately 4 mile long Donna Canal. The State turned the results over to their Superfund Program to begin the process of assessment and clean up.

"For a period of four years following the discovery of high levels of PCBs in fish tissue in the Donna Canal by the USEPA, the Texas Natural Resource Conservation Commission, in cooperation with the Texas Department of Health and Texas Parks and Wildlife Department, conducted a series of investigations aimed at identifying the source of PCB contamination in the Donna Canal and associated reservoirs. Unfortunately, the subsequent (three) water, (two) fish and (three) bottom sediment sampling efforts brought us no closer to finding a source of the PCBs. Later (in 1998) after the first Superfund Site Discovery and Assessment investigation yielded equally empty results, we felt it was time to get help. Today, I am pleased to say that, not only have we been able to narrow the potential source of PCB contamination to an area of the canal approximately 90 meters long, the suspended sediment sampling results from [USGS] studies have enabled us to refocus our Superfund Site Discovery and Assessment investigation efforts and I am confident that this project will be in remediation mode by this Fall. Of course, the real benefactors of your work are the people of the Rio Grande Valley who will have one public health problem less to contend with." **(**Roger Miranda, Texas Natural Resource Conservation Commission, March 2001).

State of Mississippi—In 2000, the State of Mississippi convened a Fish Advisory Task Force to develop procedures regarding fish consumption advisories for organochlorine compounds and other contaminants. NAWQA demonstrated that elevated organochlorine levels have persisted in fish in this part of the country longer than anticipated by most managers. Concentrations of total DDT collected from 30 of the 41 sites sampled in the Mississippi Embayment exceeded guidelines established to protect wildlife. In fact, fish collected in 1995 showed that the highest concentrations of total DDT in fish tissue throughout the entire Mississippi River drainage were in the Mississippi Embayment study area. Streams demonstrating elevated levels in fish by USGS, such as some in the Delta region in Mississippi, are included in the preliminary state fish-consumption advisories, minimizing necessary sampling by the State and, therefore, resulting in cost-effective and timely management decisions.

Managing water-resources in National Parks

USGS has worked with the National Park Service (NPS) to assess water-resources in more than 35 federally managed areas across the Nation. Many of these areas strive to balance the maintenance of pristine conditions with increasing development outside the preserved areas. NAWQA findings, as well as sampling and monitoring protocols, have been used to improve management and protection of water resources in areas throughout the nation, including in Big Cypress National Preserve and Everglades National Park, Florida; Buffalo National River, Missouri, Big Thicket National Preserve, Texas, and St. Croix National Scenic Riverway, Minnesota.

Atlanta, Georgia**—**USGS and NPS assessed the occurrence of fecal-indicator bacteria in the Chattahoochee River National Recreation Area near Atlanta, Georgia. Bacteria concentration data are available on the Internet so that the public can make informed and real-time decisions about health risks associated with swimming, fishing, and paddling the river.

Boston, Massachusetts**—**USGS and NPS assessed the Saugus River at the Saugus Ironworks National Historic Site near Boston, Massachusetts to improve understanding of impacts of watershed development on water quality. The agencies have developed a display in the visitor center that demonstrates real-time streamflow and water-quality information, allowing comparisons of water-quality conditions in the Saugus River to other rivers in the Boston metropolitan area.

Texas Panhandle**—**USGS worked with NPS to determine if historical oil and gas operations had, or were, polluting Lake Meredith, a large water-supply reservoir and National Recreation Area in the Texas Panhandle. The study, completed in 2000, showed no appreciable pollution of sediments in the lake.

Las Vegas, Nevada**—**USGS and NPS assessed the occurrence of synthetic organic chemicals, and possible preliminary signs of endocrine disruption in carp in the Lake Mead National Recreational Area, Nevada. The findings led to the posting of the Las Vegas Wash inlet, and to the formation of the Lake Mead Water Quality Forum of local, state, and federal agencies, formed to enhance communication and cooperation on Lake Mead water-quality issues.

"NAWQA Nevada Basin and Range investigations determined that synthetic organic compounds were present in bottom sediments of Las Vegas Bay in Lake Mead. Subsequent cooperative investigations by the National Park Service and the NAWQA Program have provided valuable information on the sources and potential effects of these compounds on humans and aquatic wildlife in this important National Recreation Area." **(**Alan O'Neill, Lake Mead National Recreation Area, 2001, USGS Circular 1170).

Making connections to receiving waters

Each NAWQA assessment adheres to a nationally consistent study design and methods of sampling and analysis, so that water-quality conditions in a specific locality or watershed can be placed in a broader context. The design allows a multi-scale approach that helps to take into account both the needs of the local watersheds and basins and the larger water resource networks that connect them, such as the Mississippi River Basin, Great Lakes, South-Florida Everglades system, and the Chesapeake Bay watershed. This is critical because local decisions on the effects of land use or human actions in individual watersheds can contribute significantly to the cumulative or overall impact on the quality of the downstream resource and receiving water. For example, NAWQA studies show that a considerable amount of total nitrogen originates from watersheds in the Mississippi River Basin very distant from the Gulf of Mexico. The multi-scale information, as shown in the Mississippi River Basin, helps to contribute to successful solutions and actions at the local, state, interstate, and federal level—all of which are needed because of the interconnections of water resources, communities, and ecosystems across great distances, regardless of political boundaries that may govern jurisdiction over resource management and use.

***Mississippi River Basin and the Gulf of Mexico*—**NAWQA scientists participate in a multi-agency effort, coordinated by the White House Committee on Environmental Natural Resources (CENR), to assess nutrient enrichment, eutrophication, and the effects of hypoxia (low oxygen conditions) in the Gulf of Mexico. Specifically, NAWQA is modeling sources and transport of nutrients using a spatially referenced computer model throughout the Mississippi River watershed. The model tracks the sources (including point sources, fertilizer, livestock wastes, nonagricultural land, and atmospheric deposition) and movement of nutrients in individual stream reaches across the watershed. The effort has demonstrated key roles that hydrology and natural processes play in the transport of nutrients to, and eutrophication in, the Gulf of Mexico. Specifically, closer proximity of nitrogen sources to large streams and rivers increases the transport of nutrients to the Gulf. This is because nitrogen is not removed as readily in the large streams and rivers by natural processes as in the smaller tributaries and is, therefore, much more likely to reach a coastal area if it originates close to a larger river. As a result, some watersheds in the Mississippi River Basin are much more significant contributors of nitrogen to the Gulf of Mexico than others, despite similar nitrogen sources or similar distances from the Gulf.

"The NAWQA Program is essential to understanding the impact of land-use changes on the quality of water flowing to the Great Lakes. Currently, there are two NAWQA study units in the Great Lakes, the Western Lake Michigan study unit and the Lake St. Clair-Lake Erie study unit. Findings are directly applicable to resource managers and planners and transferable throughout the Great Lakes Basin." (Quote is included in the "Legislative and Appropriations Priorities for the 106th Congress, Second Session" by the Great Lakes Commission. These priorities were formally endorsed by the eight-state Commission membership).

***"NAWQA has been enormously helpful in synthesizing data and developing a better understanding of a key ecoregion of the Great Lakes. Contributions from this study will be useful for years to come as this region is managed as an integrated natural resource*."** **(**William C. Sonzogni, University of Wisconsin-Madison, State Laboratory of Hygiene, 2001, USGS Circular 1156).

"The synthesis reports produced under this [NAWQA] Program are highly valued as support for decision-making on restoration activities in the Everglades ecosystem, including those involving the Comprehensive Everglades Restoration Plan, an 8-billion dollar project being undertaken jointly by the U.S. Corps of Engineers and the South Florida Water Management District. Data from the NAWQA Program are also vital to supplement and interpret information from other water quality assessment activities, including major monitoring efforts conducted by the South Florida Water Management District, Everglades National Park and Biscayne Bay National Park. The NAWQA Program is successful because it combines technical excellence in data collection with scientific soundness and objectivity in reporting." (Garth W. Redfield, Ph.D., Environmental Monitoring and Assessment Division, South Florida Water Management District, March 2001).

"As the largest freshwater wetland in the continental US, and one identified as being critically endangered by farming, drought, development and drainage in its watershed, the Florida Everglades has the misfortune to exhibit some of the highest concentrations of mercury in its fish and wildlife…The contributions of the USGS NAWQA Project team have been of vital importance to the [South Florida Mercury Science] Program. The USGS has brought together scientists of many disciplines and enabled the South Florida Mercury Science Program to develop a deeper understanding of the scope, scale, status and trends of mercury problems in Florida. This has thereby greatly enhanced our ability to model and manage the factors that contribute to this problem." (Dr. Thomas Atkeson, Florida Department of Environmental Protection, April 2001).

"Potomac NAWQA studies are contributing valuable information on water quality/land use issues vital to effective management of the Chesapeake Bay ecosystem." *(*Dr. Emery Cleaves, Maryland Geological Survey, Baltimore, Maryland, 2001, USGS Circular 1166).

Improving strategies and protocols for monitoring, sampling, and analysis

Local, State, tribal, and federal organizations recognize the value and application of the NAWQA Program's consistent and comparable monitoring designs and sampling methodology. Many have recognized that other available data have limited applicability because samples are not systematically collected as part of an interdisciplinary and long-term evaluation of the total resource, but are biased to a specific geographic area, problem, or medium at a single point in time.

"NAWQA data on benthic invertebrates is a major contribution to the State of Hawaii because the data have never been collected in Hawaiian streams and never before in conjunction with such a wealth of water-quality parameters. The information could provide the basis for an important new component in water-quality monitoring in Hawaii, which would be especially useful for volunteer monitors and educational groups." (Dr. Carl Evenson, University of Hawaii at Manoa, June 2004, USGS Circular 1239)

"The California State Water Resources Control Board has worked closely with the U.S. Geological Survey to develop a comprehensive monitoring and assessment program for California's groundwater basins. The approach, methods, and results from NAWQA studies have been fully integrated into California's plans to evaluate ground-water quality on a statewide basis." **(**Arthur G. Baggett, Jr., State Water Resources Control Board, June 2004, USGS Circular 1238)

"The Yellowstone River Basin NAWQA program has been beneficial to the State of Wyoming, particularly to the Department of Environmental Quality's water-quality monitoring and assessment efforts. The ecological, bacteria, water quality, and streamflow data collected have provided DEQ with the ability to assess the water quality much more comprehensively than what would be possible with DEQ data alone." (Jeremy Zumberge, Monitoring Program, Wyoming Department of Environmental Quality, June 2004, USGS Circular 1234)

"The USGS Trinity NAWQA Program has been an invaluable resource for the Texas Natural Resource Conservation Commission [TNRCC] and the Texas Clean Rivers Program. Since 1993, NAWQA hydrologists and biologists have provided the TNRCC staff and Texas Clean Rivers Program partners with their technical expertise on data analysis procedures and monitoring and assessment protocols. As the challenges in data assessment and monitoring continue for the Texas Clean Rivers Program, the TNRCC will look to the USGS and the lessons learned from the Trinity NAWQA Program." (Sally C. Gutierrez, Water Quality Division, Texas Natural Resource Conservation Commission, 2001, USGS Circular 1171).

State of Colorado—At the request of the Colorado Department of Public Health and Environment, USGS compiled available data and reports on organic compounds in water, bed sediment, and fish tissue in Colorado streams. The compilation included information from the three NAWQA assessments in the South Platte, Rio Grande, and Upper Colorado River Basins in Colorado. This request was done in response to an USEPA Audit Report of the Colorado Water Quality Standards, Monitoring, and Reporting Program, which found that "… although Colorado's monitoring program met statutory requirements, it had no systematic process to obtain organic-pollutant-monitoring data. Without these data, Colorado cannot identify water impaired by organic pollutants." USGS developed and implemented a monitoring plan for synthetic organic compounds in the South Platte River Basin in collaboration with the State of Colorado. The plan builds on NAWQA monitoring from 1992 to 1995 and on NAWQA monitoring sites established to assess changes in water quality over time.

***State of Idaho*—**As follow-up to the NAWQA assessment in the Snake River Basin, USGS worked with the Idaho Department of Environmental Quality officials to develop a monitoring strategy for assessing trends in water-quality conditions and biological communities in the middle Snake River.

***State of New Jersey*—**USGS works with the New Jersey Department of Environmental Protection and the New Jersey Geological Survey to develop surface- and ground-water-monitoring networks. The statewide networks are designed to measure the status of and trends in water quality, and to assess contaminant levels and pollutant loads in association with different land uses. The networks support the information needs of the State's watershed and TMDL programs. Both the surface- and ground-water networks follow the monitoring design of the NAWQA program.

***Wind River Environmental Quality Commission of the Shoshone and Arapahoe Tribes, Wyoming*—**The Wind River Environmental Quality Commission of the Shoshone and Arapahoe Tribes designed an ambient ground-water-quality-monitoring network that is based on NAWQA randomization techniques and well selection criteria.

Local, State, tribal, and federal organizations also recognize the value and application of NAWQA's sampling methods and protocols for measuring water quality and biological health.

State of Wymoning—Selected NAWQA protocols for aquatic invertebrate and fish communities were adopted in 2004 by an interagency working group that includes the State of Wyoming, and Federal and other agencies, and incorporated in an aquatic ecology monitoring plan. This plan was prepared to document ecological conditions and to assess the effects of resource development, including coal-bed natural gas, in the Powder River Basin of northeastern Wyoming.

"Data collected via NAWQA on fish community composition has provided valuable information to the Wyoming Game and Fish Department, assisting in our effort to document native species distributions and their habitat preferences in northeast Wyoming."
*(*Bob McDowell, Wyoming Game and Fish Department, Sheridan Region, Summer 2004)

State of Illinois—As part of their continuing program to update and maintain expertise in water-quality sampling, the Illinois Environmental Protection Agency (IEPA) compared NAWQA low-level water-quality sampling techniques with their own protocols for sampling public-water supplies. This combined effort between NAWQA scientists and IEPA was an evaluation that resulted in modifications to the IEPA sampling strategy.

State of Idaho—NAWQA biological and habitat protocols were integrated into Idaho's statewide surface water-quality monitoring network. Previous network designs by the state focused primarily on water chemistry. The cooperative monitoring program between USGS and the Idaho Department of Environmental Quality, which consists of more than 50 USGS stream-gaged monitoring sites, allows the State to assess long-term trends in water quality, evaluate in-stream beneficial uses, such as aquatic life, recreation, and drinking water, determine contaminant levels in fish tissue, and estimate pollutant concentrations and loads (for use in the TMDL process).

State of Montana—The Montana Department of Environmental Quality used NAWQA protocols in its aquatic ecology sampling programs.

"The Montana Department of Environmental Quality has used NAWQA data for addressing TMDL issues within the Yellowstone and Clark Fork River watersheds. We have also worked together in the field with the NAWQA Program to develop Montana's statewide monitoring design and sampling protocols. Data that were collected side-by-side using both State and NAWQA protocols were compared. This helped refine the State of Montana's approach to biological monitoring. We also adopted NAWQA's approach for sampling sediment for trace metal analyses." (Randy Apfelbeck, Monitoring and Data Management Bureau, Montana Department of Environmental Quality, 2001)

State of Pennsylvania—The Pennsylvania Fish and Boat Commission uses NAWQA procedures and data on fish communities from the Allegheny-Monongahela, Delaware River, and Lower Susquehanna River Basins in their statewide Index of Biotic Integrity.

State of Colorado—The Colorado Department of Public Health and Environment uses NAWQA sampling protocols to monitor water quality in the agricultural areas of the Grand Valley and Uncompahgre Valley. Because pesticides were frequently detected by the NAWQA Program, the State of Colorado has included the monitoring of pesticides for the first time.

City of New York, New York—NAWQA methods are used in a time-series monitoring project with the City of New York to assess the occurrence of urban and residential pesticides in the Croton Reservoir system. This reservoir system supplies about 10 percent of the New York City water supply.

States of Minnesota and North Dakota—The States of Minnesota and North Dakota use NAWQA findings and procedures to establish an Index of Biotic Integrity scoring system for use in the Red River of the North Basin. The procedures were adopted in 1997 to improve assessments of water quality.

State of Idaho—The Idaho Department of Environmental Quality uses NAWQA fishery information in their Index of Biotic Integrity to assess aquatic life conditions in large rivers of Idaho.

Pacific Northwest—NAWQA information on fish assemblages, along with other state and federal agency information, was used to complete a classification of 130 freshwater fish species in the Pacific Northwest. The classification included a summary of attributes on origin, pollution tolerance, adult habitat, adult feeding, and temperature preference. The regional classification of fish species helps managers and researchers evaluate water conditions and recognize the importance of biological measures of water quality.

Communication of findings

USGS is committed to effective and timely communication of findings to managers, planners, and decision makers at all levels of government, environmental and conservation organizations, academia, industry, consulting and engineering firms, and the general public. The findings are presented in multiple formats in order to meet the diverse needs of the many different users—ranging from raw data, methodology, models, technical documents, and journal articles to concise, colorful, nontechnical forums, such as pamphlets and videos. The NAWQA Program has published more than1,000 products since its inception in 1991. Direct access to summary assessments, technical publications, data, and maps can be accessed at http://water.usgs.gov/nawqa.

NAWQA Contributes to Heinz Center Ecosystem Report - NAWQA was a primary contributor to the report, "The State of the Nation's Ecosystems: Measuring the Lands, Waters, and Living Resources of the United States", by The H. John Heinz III Center for Science, Economics and the Environment. Stream and ground water quality data collected nationally in a consistent manner as part of the NAWQA Program were provided for farmlands, forests, and urban indicators. The report incorporated NAWQA nutrient, pesticide, trace element, and volatile organic compound data in its examination of the Nation's lands, waters, and living resources.

State of Nevada**—**USGS, in cooperation with the Nevada Bureau of Mines and Geology, the Nevada Division of Environmental Protection, and the Nevada Bureau of Health Protection Services, published a pamphlet that describes (1) NAWQA findings on radon in ground water of western Nevada, and (2) recommendations by state agencies on how people can test their homes for radon and what actions to take if unhealthful levels are detected.

State of Washington**—**In collaboration with the Washington State Department of Health, USGS published a brochure that describes (1) NAWQA findings on elevated DDT concentrations in bottom fish in the Yakima River and tributaries, and (2) possible health effects and recommendations to reduce the exposure of this insecticide to the general public.

State of Kansas**—**In cooperation with the Kansas State Board of Agriculture, USGS published an educational video "Herbicides, Water Quality, and You" that describes factors affecting the occurrence of atrazine in streams and information to the farming community about ways to reduce transport of herbicides to streams.

State of Colorado**—**A USGS video "South Platte River—Lifeline of a Region" was developed to describe the many factors affecting water quality in the South Platte River, from its origins in the Rocky Mountains of Colorado, through the Front Range cities, and across the plains into Nebraska. The video includes interviews with individuals from the Denver Water Board, Colorado Department of Public Health and Environment, Colorado Division of Wildlife, USGS, and USEPA. It is used as an educational tool by secondary schools, colleges, and universities, and as an outreach tool for citizens, non-governmental organizations, watershed groups, and state and federal agencies.

State of Arkansas**—**A USGS fact sheet summarizing NAWQA findings on water-quality conditions in the Ozark Plateaus was developed for Arkansas Stream Team water-quality workshops for citizens, sponsored and supported by the Arkansas Game and Fish Commission. The citizen-based Arkansas Stream Teams "adopt" sections of streams throughout Arkansas for stream bank rehabilitation and protection.

State of Georgia—Teachers and officials at all levels of government throughout Georgia use a USGS-NAWQA poster entitled "Everyone Lives Downstream" for education and outreach about water-quality issues related to urban development of the Atlanta Metropolitan area. About 15,000 posters were distributed. This poster was also the model for a poster developed jointly by USGS and Israeli, Jordanian, and Palestinian scientists working on the Middle East Peace Process.

Adirondack Mountains, New York—NAWQA scientists in the Hudson River Basin worked with the River Watch Network, the Adirondack Park Interpretive Centers, and the Adirondack Teacher's Center to help local high school teachers expand their earth-science curriculum. The program gives the schools the opportunity to measure chemical, physical, and biological characteristics of streams in their area and to interact with other schools and water-resource professionals in evaluating those data.

State of New Hampshire—USGS participates in a New Hampshire Consortium with other federal agencies, such as USEPA, New Hampshire Departments of Environmental Services and Health and Human Services, and Dartmouth College, to help answer questions related to arsenic contamination in New Hampshire and its possible environmental and health effects. This consortium grew out of increased concern about arsenic in drinking water on the part of citizens and state officials. Outreach efforts by the consortium include a regional arsenic conference, a display at the New Hampshire Drinking Water Exposition, and a fact sheet.

Southern California—NAWQA scientists and researchers serve as technical advisors on local and state task forces and advisory committees throughout the Nation. As an example, USGS is represented on a task force in southern California concerned with elevated nitrogen and total dissolved solids in surface and ground water. This task force includes representatives of all the major water purveyors and wastewater dischargers in an area that serves the water-resource needs for more than 4 million people.

"Several federal agencies publish technical information in formats designed to meet the needs of various client groups. An excellent example of this tiered approach is the publishing strategy of the U.S. Geological Survey. This agency publishes fact sheets, circulars, and several forms of technical reports that are designed to communicate information to a diversity of potential users." **(**Cited in *Journal of Ecological Applications*, vol. 10 (4), p. 1001).

"As one involved in sharing information with both the public and other agencies addressing water resources issues in the Shenandoah River Basin, the Potomac NAWQA study has been quite helpful. This particular publication, summarizing a considerable amount of water quality data through informative graphics and excellent maps, should serve as a convenient reference to others interested in knowing more about our valuable water resources." (Mr. Thomas Mizell, Virginia Department of Environmental Quality, 2001, USGS Circular 1166).

"One of the best national studies I have seen on pesticides (and nutrients) in surface and ground waters is USGS Circular 1225 "The Quality of Our Nation's Waters: Nutrients and Pesticides." The report was developed as part of the excellent National Water-Quality Assessment (NAWQA) Program. It is posted on the web. A lot of other USGS pesticide information is [also] posted." (Barry Tonning, TetraTech, March 2001).

Contacts for additional information:

If you have questions, comments, or would like to be added to our information distribution list, please contact:

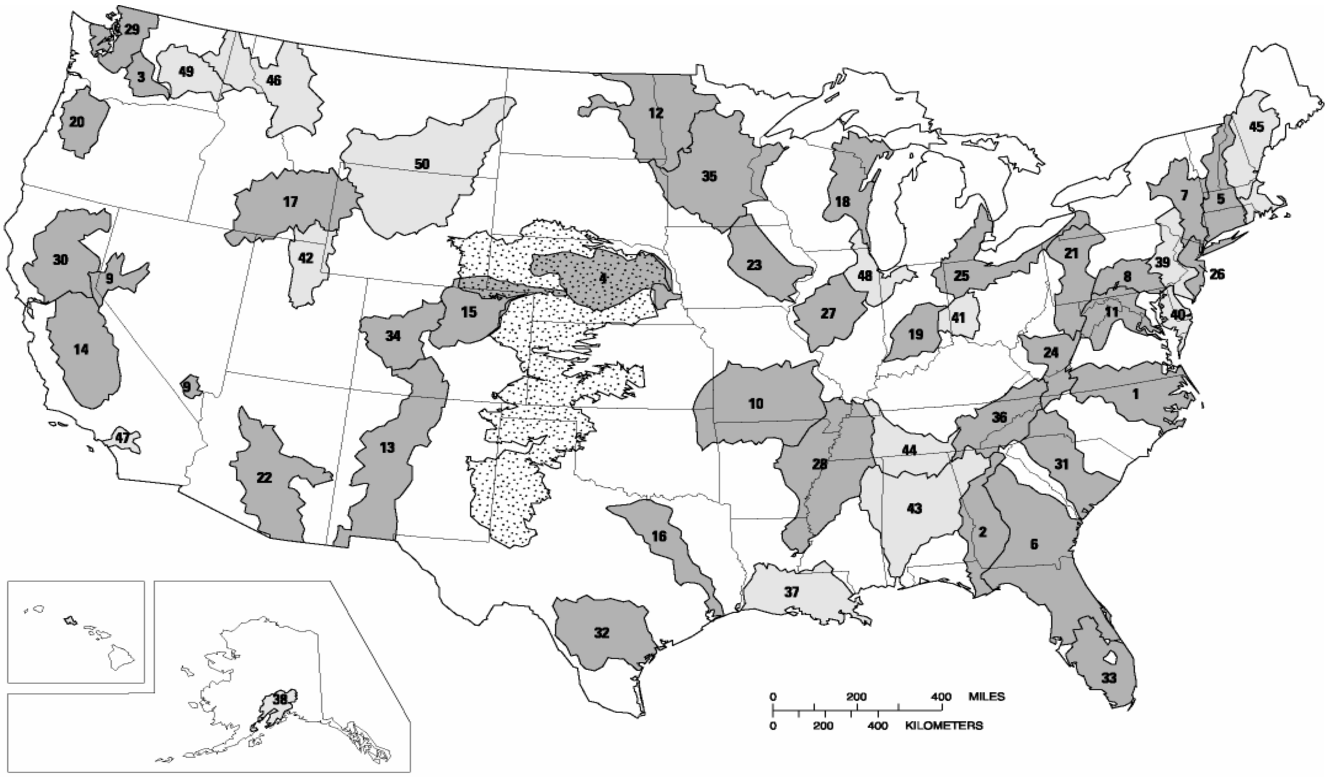
Chief, Office of Water Quality
Timothy L. Miller
tlmiller@usgs.gov
(703) 648-6868

Chief, National Water-Quality Assessment Program
Donna N. Myers
dnmyers@usgs.gov
(703)-648-5012

Pixie Hamilton
NAWQA Hydrologist and Communications Specialist
pahamilt@usgs.gov
(804)-261-2602

For access to NAWQA publications, data, and maps:

http://water.usgs.gov/nawqa



River basin and aquifer assessments, conducted 1991–98

1 Albemarle-Pamlico Drainage Basin
2 Apalachicola-Chattahoochee-Flint River Basin
3 Central Columbia Plateau
4 Central Nebraska Basins
5 Connecticut, Housatonic and Thames River Basins
6 Georgia-Florida Coastal Plain
7 Hudson River Basin
8 Lower Susquehanna River Basin
9 Las Vegas Valley Area and the Carson and Truckee River Basins
10 Ozark Plateaus
11 Potomac River Basin
12 Red River of the North Basin
13 Rio Grande Valley
14 San Joaquin-Tulare Basins
15 South Platte River Basin
16 Trinity River Basin
17 Upper Snake River Basin
18 Western Lake Michigan Drainages
19 White River Basin
20 Willamette Basin
21 Allegheny and Monongahela River Basins
22 Central Arizona Basins
23 Eastern Iowa Basin
24 Kanawha-New River Basins
25 Lake Erie-Lake Saint Clair Drainages
26 Long Island-New Jersey Coastal Drainages
27 Lower Illinois River Basin
28 Mississippi Embayment
29 Puget Sound Basin
30 Sacramento River Basin
31 Santee River Basin and Coastal Drainages
32 South-Central Texas
33 Southern Florida
34 Upper Colorado River Basin
35 Upper Mississippi River Basin)
36 Upper Tennessee River Basin

River basin and aquifer assessments, to be completed in 2001

37 Acadian-Pontchartrain Drainages
38 Cook Inlet Basin
39 Delaware River Basin
40 Delmarva Peninsula
41 Great and Little Miami River Basins
42 Great Salt Lake Basins
43 Mobile River Basin
44 Lower Tennessee River Basin
45 New England Coastal Basin
46 Northern Rockies Intermontane Basins
47 Santa Ana Basin
48 Upper Illinois River Basin
49 Yakima River Basin
50 Yellowstone River Basin

High Plains regional aquifer assessment, to be completed in 2004